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THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

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Chronicle and Comment

Finance Committee Chairmanship

PAST-PRESIDENT ALDEN will serve during the remainder of the present administrative year as chairman of the Finance Committee of the Society. The chairmanship became vacant with the lamented passing of Horace M. Swetland. Mr. Alden has been a member of the Committee from the first of the year. W. L. Batt has been added as a member of the Committee by President Crane, so that it can proceed in its important work with full quota of five members. It is the duty of the Finance Committee to make recommendations to the Council as to the expenditures necessary for the work of the Society during each successive fiscal year. The Finance Committee has, under the direction of the Council, supervision of the financial affairs of the Society, including the books of account. A meeting of the Committee is scheduled to be held in September.

Safety Code for Forging Is Proposed

THE Sectional Committee on Safety Code for Forging, organized under the procedure of the American Engineering Standards Committee and sponsored by the National Safety Council and the American Drop-Forging Institute, has issued a tentative draft of a code after about a year of work. The code is intended primarily to be a guide in properly installing forging machinery to safeguard the operators from injury. It is, of course, not mandatory but is intended to serve largely as a basis for careful attention to forging equipment and operations by companies conducting forge-shops. The proposed code was printed in the June issue of *National Safety News*.

Those who study the code and wish to offer suggestions as to changes in or additions to it should communicate with the National Safety Council, 168 North Michigan Avenue, Chicago, or with the office of the Society, prior to Sept. 15.

Data on Crankcase-Oil Dilution

ONE of the outstanding problems awaiting solution by automotive engineers is that of crankcase-oil dilution. Many experimenters are working upon it, and the Society is vitally interested in the matter. The Research Department has from time to time obtained information from individual laboratories that have been investigating the problem. The inadequacy of the material at hand, however, was realized, and an attempt has been made to get the views of manufacturers concerning the various phases of the problem so as to be able to present to the members of the Society a cross-section of the ideas of the men who are producing automobiles and those who have a very close contact with them afterward. For this purpose a questionnaire was recently sent out to a selected list of persons who have studied the problem, 26 of whom very generously replied, affording a fund of useful and pertinent data.

Information was sought and obtained as to the views of the manufacturers relative to the general situation and to such phases of it as the causes of dilution, the design factors controlling it, its effects and suggested remedial measures, such as eliminating the dilution by appropriate devices or alleviating the conditions by other means. The material has been tabulated and put into form for presentation to the members. It will be found in this issue of THE JOURNAL beginning on p. 117.

Automobile Taxes

IN addition to the excise tax, which is a special form of taxation on motor vehicles, there are, in the different jurisdictions of the Country, taxes based on the horsepower and weight and also the tax on gasoline. The city of Chicago has provided for a wheel tax and in at least one State there is local taxation of automobiles.

The States are, of course, the principal governmental bodies that have provided for the taxation of automobiles. The taxes include the general levies on property, for the benefit of schools, these being evaluated according to the amount of property owned. In the opinion of a committee that represents the automotive industry, the States should be the sole taxing agents, and the sum total of special taxes on automobiles should be restricted to the amount of funds required for the maintenance of highways and the various highway departments. The capital outlay for roads should be provided by the people in general. Such a policy requires, of course, that "maintenance" should be accurately defined. Much headway has been made in the establishment of mutually helpful procedure by the automotive industry and the Federal and the State highway bureaus. This work, supplemented by further consistent efforts, will be of invaluable benefit to the public generally. The plea that Dr.

Goldbeck, of the United States Bureau of Public Roads, made at the meeting of the Society held at West Baden, Ind., some years ago, for close cooperation between the highway and the automotive engineers, had a very advantageous effect. For some years the Society, through its Highway Committee and other committees, has participated in studies on highway problems made at the Bureau of Public Roads experimental farms at Arlington, Va. In furtherance of this work the Highways Committee of the Society is to hold another session in the City of Washington early this month.

Operating Cost of Passenger Cars

IT is deduced from bulletins that have been issued by Iowa State College that the cost of operating in 1923 the 536,000 passenger cars and 40,000 trucks registered in Iowa, was $408,000,000, for gasoline, oil, tires, repairs, interest, depreciation and other items relating directly to the operation of the vehicles. This cost for the passenger cars separately was $285,000,000. Records were kept by reliable persons of the expenditures for operating 11 representative passenger-cars. On the average the cost of operation was 10.27 cents per mile. The conditions of the cars as to efficiency varied greatly. Cars of different ages were taken for the purpose of securing an average result representative of the cars running over Iowa roads. The depreciation and maintenance charges amounted to somewhat less than half the operating cost. The actual mileage-cost was about three-quarters of the total cost. The driving expense was 7.3 cents per mile for the composite car. The average amount of travel of the cars during the year was 6200 miles.

A feature of the investigation was the figuring of depreciation on a mileage basis. This is known as the traight-line method, the depreciation being constant for each mile driven. It was estimated that the average life of cars is 6 years. The total expected service of a new car was assumed to be 36,000 miles. The depreciation figure was obtained by dividing the cost of the car new by 36,000. The purpose of this method was to arrive at figures independently of fluctuating commercial values and conditions.

Incidentally, it was concluded that a reduction in fuel consumption of 10 per cent would save the car owners of the State $6,000,000 per year. The opinion was expressed also that the total operating-cost increases as the amount of fuel used increases, reduced fuel-consumption resulting in corresponding saving in tires, wear and depreciation. The point made was that conditions requiring heavy fuel-consumption are generally more severe on the car. This, of course, constitutes one of the best possible arguments for the extension of good-road systems. It was stated incidentally that automotive engineers are confronted with the problem of reducing an automobile driving-cost that is 14 times the amount spent for building and maintaining roads.

The bulletins referred to are Nos. 64, 65 and 67 of the Iowa Engineering Experiment Station, Ames, Iowa.

Standards Approved by Society Members

THE last step in the procedure for approving reports of Divisions of the Standards Committee is the letter-ballot of the voting members of the Society. For the reports submitted and approved at the Standards Committee Meeting at Spring Lake, the letter-ballot closed on July 24.

Although the approval of these reports by a majority vote, as required by the Standards Committee Regulations, is only to be expected, the letter-ballot really represents an opportunity for Members still of the opinion that the reports merit criticism to so indicate. A relatively large number of negative votes is rightly considered as evidence that a report merits the reconsideration of the Division that submitted it, especially if the negative votes are supported by sound engineering reasons. The Council may therefore withhold such a report from publication in the S. A. E. HANDBOOK, pending reconsideration by the proper Division.

The complete vote on all the recommendations submitted at the Summer Meeting is recorded in the following table. The first column gives the number of affirmative votes cast; the second column, the number of negative votes; and the third column the number of those casting ballots who did not vote either way on certain recommendations. The ballots cast represent 13 per cent of the voting members of the Society, a percentage that has held practically constant for several years. When it is taken into consideration that over 100 of these are straight "yes" or "not voting" ballots, it will be appreciated that a larger return would probably only increase the number of such ballots and not make the total return of any more real value.

	Yes	*No*	*Not Voting*
AGRICULTURAL POWER EQUIPMENT DIVISION			
Tractor Leather Driving-Belts	120	6	211
Tractor Speeds	125	2	210
Tractor Specifications (Cancellation)	124	1	212
Tractor Power Take-Off Speed	125	1	211
Tractor Canvas and Rubber Driving-Belts	122	3	212
BALL AND ROLLER BEARINGS DIVISION			
Wide-Type Annular Ball-Bearings	210	1	126
LIGHTING DIVISION			
Passenger-Car Head-Lamps	190	2	145
Electric Incandescent Lamps	185	0	152
Lamp Glasses	191	0	146
Bases, Sockets and Connectors	194	0	143
Motor-Vehicle Acetylene Head-Lamps	174	1	162
NON-FERROUS METALS DIVISION			
Wrought Non-Ferrous Metal Alloys	182	0	155
Aluminum Alloy Specifications	183	0	154
Soft or Annealed Copper Wire	183	0	154
PARTS AND FITTINGS DIVISION			
Flared-Type Tube-Fittings	192	2	143
Soldered-Type Tube-Fittings	191	1	145
Passenger-Car Bumper Mountings	182	1	154
Wire Cloth	174	1	162
SCREW-THREADS DIVISION			
High Nuts	203	10	124
Dimensional Tolerances	211	0	126
SPRINGS DIVISION			
Motor-Truck Springs (Cancellation)	168	0	169
Passenger-Car Springs (Cancellation)	170	0	167
Leaf-Spring Stock	172	0	165
Leaf-Spring Definitions	168	8	161
Leaf-Spring Nibs	173	0	164
Spring Off-Sets and Resulting Ends	175	0	162
Leaf-Spring Tests	175	1	161

MEETINGS OF THE SOCIETY

TRANSPORT MEETING IN SEPTEMBER

Program of Papers on Buses, Trucks and Rail-Cars Includes British Authority

National meetings of the Society will be resumed in the fall with the holding of the Automotive Transportation Meeting in New York City, Sept. 18 and 19. This 2-day gathering will include several meetings devoted to discussions on the design, operation and maintenance of motorbuses, motor trucks and motor rail-cars. All but one of the sessions will be held in the Hotel Pennsylvania. Inspection trips will be made through the maintenance shops of the Fifth Avenue Coach Co. and those of one of the larger operators of motor-truck fleets. The New York Railroad Club will meet jointly with the Society in one of the sessions which will be devoted to subjects of particular interest to railroad engineers.

Prominent in the list of speakers will be James Paterson of London, England. Mr. Paterson is managing director of Carter-Paterson Ltd., England's foremost firm of shippers. Under his direction one of the outstanding examples of successful motor-truck transportation on a large scale has been built up. His firm has developed operating methods, vehicles, bodies and trailers, the description of which should be of great interest to American engineers.

J. H. Hoffman, vice-president of the Motor Haulage Co., New York City, will describe the operating methods of this company, which has been unusually successful in handling an extensive motor cartage business. Only recently this organization became associated with the Long Island Railroad in the handling of less-than-carload freight in the Metropolitan area and along the railroad's lines leading out of New York City.

Motor rail-cars will be treated in papers by W. L. Bean, mechanical engineer of the New York, New Haven & Hartford Railroad, and J. W. Cain, manager of purchases of the American Short Line Railroad Association. Mr. Bean has experimented with gasoline-propelled rail-cars for a number of years, in fact was one of the pioneers in the application of this type of equipment. The membership of the association with which Mr. Cain is connected naturally includes many motor rail-car advocates since the short-line railroads are the ones that will profit most from the use of these economical units. Both of these papers are certain to present information of great value to automotive engineers engaged in the design and manufacture of rail-cars.

It is natural that the rapid expansion of motorbus transportation should have influenced the arrangement of the Automotive Transportation program. Two sessions will be devoted to the consideration of motorbus design and operating problems. One of the papers will be presented by F. D. Howell, of the Motor Transit Co. of Los Angeles, Cal. The Motor Transit Co. is one of the largest operating companies in the Country, running 125 cars in local and through service over some 800 miles of highway, radiating out of Los Angeles in all directions. The company operates its own maintenance, assembly and body building shops.

Motorbus body design and construction will be treated in a paper by Hugh Bersie. R. E. Fielder, chief engineer of the Fifth Avenue Coach Co., will discuss the maintenance methods of that organization as an introduction to an inspection visit that will be made to the shops where the Fifth

NATIONAL MEETINGS CALENDAR

AUTOMOTIVE TRANSPORTATION MEETING—New York City—Sept. 18-19

AERONAUTIC MEETING—Dayton—Oct. 2

PRODUCTION MEETING—Detroit—Oct. 22-24

SERVICE ENGINEERING MEETING—Cleveland—Nov. 18-19

MOTORBOAT MEETING—New York City—Jan. 7, 1925

ANNUAL DINNER—New York City—Jan. 8, 1925

ANNUAL MEETING—Detroit—Jan. 20-23, 1925

THE CARNIVAL—Detroit—Jan. 21, 1925

Avenue buses are overhauled and repaired. V. E. Keenan, superintendent of the bus division of the United Electric Railways Co. of Providence, R. I., and J. B. Stewart, Jr., general superintendent of the Youngstown Municipal Railway Co. of Youngstown, Ohio, will contribute the operating experience of two public utility organizations that have found it profitable to install motorbus service. W. F. Evans, president of the Detroit Motorbus Co., will present certain of his views on motorbus design and operation.

A more complete announcement of the Automotive Transportation Meeting program with a definite schedule of the papers will appear in the September issue of THE JOURNAL.

PRODUCTION MEETING PLANS

Committee of Manufacturing Executives Organized to Select Papers and Topics

Work has been started on the program for the national meeting of the Society, devoted to automotive production problems, which will be held in Detroit Oct. 22 to 24. A committee of production executives met at the Detroit Athletic Club on July 16 for the purpose of selecting topics and problems that should be treated at the technical meetings. An effort is being made to choose only those subjects that are of current interest to production men so that the meetings will offer material of specific value to those who will attend them. The discussion at this first committee meeting was most interesting and resulted in the listing of the following subjects for consideration:

- Reduction of Wood Waste
- Automobile Glass; manufacture, specifications and salvage
- Combating Wood Checking and Warping
- Steel Body Manufacturing Methods
- Control of Rubber Composition
- Reducing the Cost of Fabrics
- Labor Problems
- Automobile Shipping Methods
- Plating and Polishing
- Supervision of Plant Maintenance
- Coining Press Operations
- Tool Salvage
- Saving Waste and Reducing Cost by Cooperative Investigations Conducted by Automobile Manufacturer and the Suppliers of Raw and Semi-Finished Materials

Additional subjects will be considered at a second meeting of the committee, to be held in Detroit on Aug. 6. Names of authors qualified to treat the subjects finally selected will be suggested.

Those present at the first committee meeting were:

T. J. Little, Jr.	Chairman of the Meetings Committee
K. L. Herrmann	Meetings Committee
C. W. Avery	Ford Motor Co.
E. J. Bouton	Chandler Motor Car Co.
John McGeorge	Oakland Motor Car Co.
L. L. Roberts	Packard Motor Car Co.
V. P. Rumely	Hudson Motor Car Co.
John Scott	Olds Motor Works
R. A. Vail	Dodge Bros.

Members who are desirous of presenting papers before the Production Meeting should communicate their wishes to the office of the Society at the earliest possible date in order to secure places on the program.

SHIDLE IS TENNIS CHAMP

Norman Shidle, noted automotive scribe, will wear the tennis laurels of the Society for the year 1924. It was not possible to play the final match in the Spring Lake singles tournament during the Summer Meeting period because of a downpour of rain on the last day. The postponed match was played recently on the courts of the Sleepy Hollow Country Club near New York City, and Mr. Shidle vanquished Coker F. Clarkson 6-4, 6-4, 6-3.

PACIFIC COAST MEMBERS MEET

Members of the Society living in the vicinity of San Francisco spent a most interesting afternoon recently when they visited the factory of the Fageol Motors Co., Oakland, Cal. Frank Fageol, president of the company, and L. E. Hollman, chief engineer, acted as hosts and explained the various steps taken in manufacturing modern motorbuses.

As a result of the great interest shown in this meeting, the committee in charge of the San Francisco activities of the Society is planning visits in the near future to several other large automotive plants. Members residing on the Pacific coast are invited to write A. A. MacCallum, secretary of the committee, offering suggestions on the expansion of local meetings in the California district. Mr. MacCallum may be addressed at 115 Montgomery Street, San Francisco.

LIQUIDATION OF FRENCH WAR FLEET

THE French Parliament has passed a final law liquidating the State commercial fleet organized during the war, and apparently this liquidation has been more successful than those attempted in other nations. Four hundred and twenty-two vessels, with a net tonnage of 1,242,595, have been sold for 247,560,000 francs. The cost of the vessels was originally 1,425,000,000 francs, so that the State lost 1,178,000,000 francs, or five-sixths of its investment. According to the French this is better than the result attained by Belgium, as good as that attained in England, and much better than results so far registered in America, which has lost 13/14 of its investment. This loss does not include that sustained in the operation of the vessels during the period of Government ownership, which is estimated at 437,000,000 francs, so that the total loss to the French taxpayer is about 1,600,000,000 francs.

The larger part of the vessels were sold to a consortium of 40 French shipping companies, which paid only a part on their purchase and gave a mortgage for the rest. The sale price was about 400 francs per ton, and a clause was attached to the deed whereby the State will participate in any increase in value of the tonnage. Vessels not suitable for purposes of French commerce have been sold to shipping interests in foreign countries.

The year 1923 saw an important revival in French shipping. Three hundred and thirty-two thousand tons of worn-out vessels were scrapped or sold, while 240,000 tons of new units were added to the fleet, giving a total tonnage at the close of the year of 3,408,000. An increase in shipping and world commerce reduced the amount of idle French tonnage from 730,000 on Jan. 15, 1923, to 351,000 on the same date of the current year. French vessels are carrying a larger percentage of French trade than before the war.—*Journal of Commerce.*

AUTOMOTIVE RESEARCH

The Society's activities as well as research matters of general interest are presented in this section

THE DANGER POINT OF DILUTION

Twenty-six Makers Report Views on Dilution Factors and Propose Remedies

What is the danger point of dilution and how often should crankcase oil be changed are questions that are not satisfactorily answered. "That depends!", although indefinite, is probably the nearest approach to a correct reply that can be expected, for conditions are so varied that a general statement cannot apply equally well to all cases. It should perhaps be possible, however, to reach definite conclusions with regard to certain phases of the general problem.

The paucity of authoritative data and the apparent lack of agreement among engineers with respect to these and other aspects of the dilution question prompted the Society's Research Department to obtain the views of a number of automobile and engine manufacturers. It was hoped that a digest of the information thus obtained might at least throw some light upon the attitude of those who have to face the problems and who come into close touch with the conditions prevailing in actual service.[1] Twenty-six engineers representing as many prominent firms of the industry very kindly presented conclusions that are based upon their experience. On p. 118 the statements of the various engineers are given in condensed tabular form *without comment or alteration of the sense intended.*

Certain of the items included in the table are difficult to summarize concisely and they may be studied best perhaps by direct reference to the table itself. Other cases will be summarized briefly in the following paragraphs.

Dilution Factors

Effect of Weather or Outside Air Temperature.—General agreement is found among the replies that lower air temperatures result in increased dilution. This is accounted for by the increased difficulty of starting and bringing the engine to stable operating conditions. Excessive use of the choke and difficulties in vaporizing the fuel are given in several cases as the direct consequences of low air-temperature that tend to increase dilution.

Effect of Jacket-Water Temperature.—All but one of the replies indicate that lower jacket-water temperatures mean increased dilution. The influence of this factor is said to be less for trucks than for passenger vehicles. Temperatures above 140 deg. fahr. are advocated in one case, whereas a range of from 160 to 170 deg. fahr. is recommended in another instance. Incomplete vaporization and combustion of the fuel and the requirement of richer mixtures are given as contributing causes of greater dilution with colder jacket-water. Fifty-per cent dilution was found in a test in which the engine was run continuously for a day with cold water circulating through the jackets.

Effect of Fuel Volatility.—Increased dilution is believed to accompany decreased fuel-volatility. Again the lesser effect on commercial vehicles is brought out. Incomplete vaporization and combustion and the necessity for higher oil-temperatures to drive out dilution are given as causes for greater dilution with heavier fuels.

Effect of Mixture-Ratio.—The reports agree in general that over-rich mixtures cause excessive dilution. One reply states that the important result of having the mixture too rich is the contamination of the crankcase oil by carbonized particles.

Effect of Piston and Ring Design.—Nine of the 16 definite replies with reference to this item indicate that piston and ring design have a bearing upon dilution, whereas six report little or no effect. The importance of using proper material for cylinders, pistons and rings is emphasized by one reply.

Effect of Wear and Piston Fits.—Ten of the 13 replies that refer to the effect of wear and piston fits indicate that these factors influence dilution. Three replies take the opposite view. The need for an effective seal between the piston and the cylinder is mentioned as a reason for having good piston fits and for keeping wear at the minimum.

Injurious Effects of Dilution.—Increased wear, noise, danger of seizure, carbonization and corrosion are mentioned among the injurious effects of dilution. Few cases of seizure seem to have been experienced. This is accounted for in one case by the increased clearance that results from greater wear with high dilution.

Danger Line of Viscosity.—No reply includes an explicit statement concerning the minimum allowable viscosity for good operation. This indefiniteness is explained in several cases by the presence of variables such as the character of lubricating systems, bearing types and proportions and contamination by dirt. One statement proposes 15-per cent dilution as representative of the safe minimum of viscosity and another differentiates between new and old engines; the latter recommends 15 per cent in the case of new engines and 25 per cent in the case of old engines.

How Often Should Oil Be Changed?—Recommendations as to frequency for changing crankcase oil vary from 300 to 2500 miles under winter and summer conditions respectively. No marked agreement is noticed among the replies.

What Remedies Are Necessary?—Improved carburetion and distribution, thermostatic control of jacket-water temperature, the maintenance of a warm oil-pan, the filtration of oil and the cleaning of air, means for quick starting, the use of automatic radiator shutters and the elimination of the choke are mentioned as possible remedies for excessive dilution. Education of automobile operators is also thought advisable.

Discussion Suggested.—Among the recommendations for suitable subjects of discussion and research the following are mentioned: the use of automatic hood shutters; the use of thermostats, oil cleaners and renovators; the amount of wear directly traceable to dilution; the danger point of dilution and viscosity; engineering facts concerning dilution, to be given in popular form for distribution among operators; facts and conclusions of engineers who represent the passenger-car, truck, tractor and oil industries.

[1] The Research Department plans to present in an early issue of THE JOURNAL a summary of the conclusions that have been drawn from the cooperative fuel investigation and other research projects that include studies of the items discussed in this article.

MANUFACTURERS' VIEWS ON DILUTION[1]

Maker	WHAT ARE THE EFFECTS ON DILUTION OF THE FOLLOWING: Weather or Outside Air Temperature	Jacket-Water Temperature	Fuel Volatility	Mixture-Ratio	Piston and Ring Design	Wear and Piston Fits
1	Dilution greater at lower temperature. Direct result of starting difficulty and delay in bringing engine to stable operating condition	Dilution greater at lower temperature. No marked difference with temperature above 140 deg. fahr.	Dilution greater at lower volatility	No answer	Design is important. Permitting oil scraped from walls to be returned to crankcase is responsible for robbing piston-rings of their lubrication	Any conditions that reduce effectiveness of seal between piston and cylinder wall tend to increase dilution
2	Dilution greater at lower temperature	Dilution greater at lower temperature	Dilution greater at lower volatility	Dilution greater with richer mixture	Design has not much to do with dilution	Poor ring and piston fits increase dilution
3	Air, engine and oil temperatures influence elimination of diluent after it gets into crankcase	Dilution greater at lower temperature	No answer	No answer	Intensive study should be made of this problem with the object of reducing blow-by to a minimum. With this accomplished the normal temperature in crankcase with proper ventilation would decrease dilution	No answer
4	Has bearing on the subject	Dilution greater at lower temperature	Has bearing on the subject	Has bearing on the subject	Has bearing on the subject	Wear has bearing on subject but not piston fit
5	Outside air temperature most deciding factor. If temperature is kept high enough, fuel that gets by piston may pass from crankcase as vapor	Dilution greater at lower temperature If jacket water is cooled to condensation point and sulphur is in fuel, sulphuric acid forms and attacks part with which it comes in contact	Determines percentage of fuel dropped during combustion. Cites an instance where enough fuel was dropped to leave a deposit similar to vaseline in crankcase	Somewhat same effect as volatility if made too rich	Much to do with the amount of fuel that passes the piston	Wear is increased
6	Rapid changes in temperature cause rapid dilution	Dilution greater at lower temperature	Does not attempt to answer this question	Does not care to answer except in treatise form	Design has little to do with this problem. Quality and workmanship most important, quality meaning material used in rings and pistons, workmanship meaning finish on cylinder and piston walls	Has little effect
7	No answer	No answer	No answer	No answer	No answer	No answer
8	No answer	No answer	No answer	No answer	No answer	No answer
9	Does not know what dilution is due to, weather or outside air conditions	No answer	No answer	No answer	Piston-ring design has much to do with dilution	The machining of cylinder-blocks at too fast a speed results in the block becoming oval and rings do not conform to walls, increasing dilution
10	Appears to be answered by Cooperative Fuel Research tests	Appears to have been answered by Cooperative Fuel Research tests	Appears to be answered by Cooperative Fuel Research tests	Appears to be answered by Cooperative Fuel Research tests	More or less an unsettled question	More or less an unsettled question
11	Dilution greater at lower temperature. Less with commercial vehicles due to continuous operation; also, larger proportion are kept in partially heated garages	Practically constant both summer and winter, except when starting. Commercial vehicles are affected less	Less effect on commercial vehicles due to average higher engine-temperature	Less effect on commercial vehicles due to average higher engine-temperature	Has very little effect on dilution. No design proof against the passing of liquid fuel	Excess liquid fuel in cylinders causes lubrication to be destroyed to the extent that piston and ring fits rapidly become poor
12	Has decided effect; cold engine has tendency to dilute oil. Dilution of 25 per cent under hard driving in warm weather will be reduced to 5 per cent	Dilution greater at lower temperature	Has direct bearing on dilution	Has direct bearing on dilution	No answer	Dilution increases wear
13	Dilution greater at lower temperature	Dilution greater at lower temperature	Dilution greater at lower volatility	No particular effect if kept within the operating range of the car	Will decrease dilution as new oil must be added frequently	No answer

14	Dilution greater at lower temperature. At period before maximum heat is reached and during idling, dilution is increased as result of insufficient air heat. Makes vaporization easy or difficult and checks or increases dilution	Dilution greater at lower temperature	Dilution greater at lower volatility. Vaporization failure due to (a) too rich mixture, and (b) insufficient heat. Gasoline does not vaporize at as low a temperature as it did a few years ago	Has effect on dilution	Has bearing on the subject	Ring fits more important than design. Pistons and rings are checks on amount of dilution reaching crankcase. Minimizing of wear on these parts is desired. Difficulty is progressive and cumulative
15	Dilution greater at lower temperature	Low temperature causes a slight increase in dilution	The less volatile the fuel, the more the driver uses choke and the worse dilution becomes. Very noticeable in city traffic	Little or no dilution results with correct mixture-ratio. Excessively rich mixture produces decided dilution	Has not found any ring design that would seriously affect dilution after rings have been worn in	Frequent starting and stopping in cold weather causes decided wear on pistons and cylinders
16	Dilution greater at lower temperature	Low temperature promotes dilution due to incomplete evaporation and combustion of the fuel and richer mixture required	Heavy fuel increases dilution due to incomplete vaporization, combustion and higher oil temperature required to drive it off from the oil	Dilution greater with richer mixture	No answer	Poorly fitting rings allow part of fuel to leak past into crankcase. This is not due to loss of lubricating value but to dirt and metal particles in oil. Film of oil containing dirt comes in contact with bearing surfaces and abrades them
17	Dilution greater at lower temperature	No answer	No answer	No answer	No answer	Cylinder wear occurs at more rapid rate with a badly diluted oil supply than with one in which the dilution does not exceed approximately 10 per cent
18	At lower temperature gasoline will not vaporize or atomize freely. Also portions of fuel evaporated will recondense and wash oil from cylinder-walls increasing dilution	Dilution greater at lower temperature Evaporated fuel at low temperature recondenses and washes oil from cylinder walls; also, a deposit of fuel on cylinder-walls results from precipitation and direct wall flow	Determines amount of fuel that will precipitate on cold walls and is decidedly important	Not so important if temperature is high enough. Rich mixture causes carbonization through admixture of oxidized carbon particles with the oil	No answer	No answer
19	Affected to the greatest extent by outside temperature; this also affects carburetion and sets up the cycle of thermal changes	Dilution greater at lower temperature. Operating temperature should be as near 160 to 170 deg. fahr. as can be maintained	No answer	No answer	No answer	Does not believe that oil dilution can be stopped or even helped to any great extent by close piston-ring fit
20	Dilution greater at lower temperature	No answer	No answer	Correct mixture-ratio, as well as proper control of temporary enrichments, helps to eliminate dilution	No answer	No answer
21	No answer	No answer	No answer	No answer	No answer	No answer
22	No answer	No answer	No answer	No answer	Gas leakage past pistons carrying with it gasoline in raw state affected by piston design	Gas leakage is affected by piston-ring fits
23	Dilution greater at lower temperature	Is greatest single influence that tends to increase or decrease dilution	No answer	Dilution greater with richer mixture	Does not feel that design has any great effect	Does not feel design has any great effect
24	Dilution greater at lower temperature. The result of using the choke and forgetting to change after engine is warmed up	Dilution greater at lower temperature. Should keep temperature as close to 200 deg. fahr. as operating conditions will permit. In winter temperature is dropped from 40 to 60 deg. fahr., causing condensation, and greatly increased dilution results	The higher the volatility the less the tendency to choke and enrich the mixture. After thoroughly warming up lower-grade fuels can be used without increasing dilution	Dilution greater with richer mixture. Rich mixture does not burn completely, thus allowing residue to pass rings and enter crankcase	Ideal piston is one that is free from any slots, holes or openings throughout its length and in addition to the sealing action of the rings it has the benefit of an oil seal for full length of skirt	Piston fits should be as close as possible without danger of seizing
25	Dilution greater at lower temperature and is proportional to length of time choke is used in starting and warming up	Dilution greater at lower temperature	Directly contributes to increased dilution	Dilution greater with richer mixture	No answer	No answer
26	Dilution greater at lower temperature	Dilution greater at lower temperature. Running cold water through water jacket for a day resulted in 50-per cent dilution	Fuel with high end-points aggravate dilution, especially when operated with cold water	No answer	Dilution will result with the best piston and ring design if the other conditions are not right	No answer

[1]Statements of engineers representing 26 manufacturers of automobiles and engines are presented in this table in condensed form without comment or alteration of the sense intended. See p. 117 for summary.

MANUFACTURERS' VIEWS ON DILUTION[1] (*Concluded*)

Maker	Injurious Effects of Dilution. Such as: Increased Wear, Danger of Seizure, Carbonization, Corrosion and Noise	What Is the Danger Line for Diluted Oil Viscosity?	How Often Should Crankcase Oil Be Changed?	Are Remedies Necessary? If So, What General Lines of Development Look Most Promising?	What Phases of the Problem Should Be Brought Out in Papers or Discussions?
1	Greatest evil results in oil losing its power of absorbing particles of road dirt, carbon, and the like, which find their way into the combustion chamber, permitting them to act as an abrasive	Variable quantity, depends on character of service and lubricating system	Every 2 weeks. For hard service weekly	Increase uniformity of distribution. Lower percentage of unburned fuel. Eliminate outside dirt. Obtain and retain an effective oil-seal	No answer
2	Increased wear, noise and danger of seizure	Not in a position to state, but believes more trouble arises from dirt	Every 500 to 1,000 miles	There are remedies, but the cost has delayed quantity production	Use of automatic hood shutters, oil cleaners and renovators, thermostat in water circulating system
3	No data concerning wear. No trouble from seizure	No answer	No answer	No answer	See data or hear discussion on the amount of wear directly traceable to dilution and what percentage of dilution or viscosity can be proved dangerous
4	Does not think danger of seizure is likely to be caused by crankcase-oil dilution	Does not feel it is possible to estimate dilution by oil viscosity	After 500 miles of use	Yes. Proper manifolding and proper grades of oil are most important	Subject of oil warrants considerable research, especially as to its value from a lubricating standpoint
5	Wear, danger of seizure and noise increase	Not the same for all engines, since the proportion of bearings and similar parts is a deciding factor and determines how often oil should be changed	No answer	Yes. Method for maintaining hot jacket-temperature and warm oil-pan temperature. Improvement of freezing solution	No answer
6	Increased wear, piston seizure, carbonization, corrosion, end play in crankshaft, flat piston pins and the like	Does not attempt to answer	About every 500 miles	Remedies are not necessary but education is	Engineering facts boiled down to the layman's language and distribution among various operators who are constantly condemning engineers and companies
7	No answer	No answer	No answer	Yes. Something more is necessary than redesigning carbureters and fitting pistons and rings. It is not their function to prevent dilution	No answer
8	20 to 30 per cent dilution will cause rapid wear of cylinders, pistons, wrist pins, and similar parts especially when there is more or less acid and water of condensation as well as gasoline in crankcase mixture	Does not believe reduction in viscosity is only difficulty that is met with in crankcase oil dilution	No answer	Keep the fuel in the combustion spaces of the cylinders: also, purify the crankcase oil as soon as possible after being diluted	No answer
9	No answer	Not prepared to say just what the danger line is	Not prepared to say but in heavy-duty engines oil should be changed as soon as it becomes thin	Recommends the use of a first-class air-cleaner. Believes no car is complete without one	No answer
10	Amount of sulphur in fuel determines the effect of corrosion	Feel more data should be obtained before making definite statement	Should have more data before making statement	No answer	Three or four papers by engineers representing different branches of the industry, that is, automobile, truck, tractor and oil. These papers should be confined to statements of facts and conclusions
11	No answer	No answer	No answer	Yes. However, conditions are being rapidly improved	No answer
12	Increases wear, carbonization, corrosion and noise. Has never had a case of seizure, so does not know what it is due to	Dependent on the body of the oil	300 miles in winter, 500 miles in summer	Yes. Should develop carburetion, manifolding, proper hot-spots and adequate thermostat to keep engine at correct operating temperature	Not so much design as education of driver in proper use of carbureter choke
13	Has not noticed any great effect, except possibly more noise	Has no definite information. Has run with as high as 50-per cent dilution with no ill effects	800 to 1,000 miles	Yes. Means of starting engine quickly and keeping warm after heating	Would like to know more about what has actually been proved in regard to the injurious effects of dilution

14	Increases wear which tends to decrease danger of seizure. Causes corrosion and noise. Carbonization will increase when piston and ring wear become serious	Believed to depend on amount of foreign material and system of lubrication	Governed by extent to which oil is contaminated	Yes. Use of air-filter and application of heat to fuel	Papers on air filtration or application of heat, particularly exhaust heat, to the fuel. Also, the necessity for education of operator and procedure to follow
15	Injurious to bearing life, but more to cylinder walls, rings and pistons. Cylinders seem to go first	Appears to be about 15-per cent dilution. Viscosity drops rapidly after this point is reached	Every 700 miles in winter	Yes. Elimination of choke. A means of easy starting. Better carburetion and manifolding	No answer
16	More noise, but little danger of seizure if engine is well worn in	No answer	Every 500 miles, and in winter more often	Yes. Better vaporization of fuel and more complete combustion. Better fuel-distribution	No answer
17	No answer	No answer	Frequent changing is beneficial	Yes. Nothing to report in progress other than improvements that have been accomplished in better distribution	No answer
18	Causes cracking when coming into contact with hot surface as the underside of piston. Carbonization results from fuel particles in oil	Engine, more or less an instrument that tells the viscosity. At low temperature friction is excessive and at high temperature viscosity is so little engine will seize	Every 500 miles	No answer	Research on lubricating oils and why they should offer so great resistance when cold and so little resistance when hot
19	Increased wear and danger from scoring	Impossible to answer owing to the fact that a highly diluted oil might be used if the engine were run at normal and less than normal speeds	1,000 miles in winter, 2,500 miles in summer	Yes. Improvement of lubrication, carburetion and manifolding	Constructive work along lines of overcoming troubles from source of dilution or eliminating dilution, also carbureter and manifold design
20	Principal effect is wear and carbonization. Corrosion usually develops in cars that have been in storage	No definite danger-line. Depends on lubrication, engine design and oil temperature	In any case every 2,000 miles	Yes. Temporarily enriching the mixture necessitates a means of reducing the danger in design of engine, intake and carbureter, therefore preventing undivided fuel from entering crankcase. Choke is worst offender	No answer
21	Rapid wear, excessive carbonization and short life of engine. Dilution results in a sludge formation	Cannot be suitably determined. Depends on engine design and type of lubricant	Does not believe any rule can be made	Add spray to interior part of upper crankcase for flushing out. Believes engine cannot be designed so that crankcase sludge will be eliminated	No answer
22	No answer	Inherent oiliness is most important factor but no definite value can be given to it	No answer	Yes. By filtration of oil, by improving manifold design and by making starting easier	No answer
23	Causes increased wear. Road dust and carbonaceous material are most injurious	No answer	Every 300 miles in winter, 500 miles rest of year	Yes. An oil filter that will positively collect all foreign matter	General phase of problem should first be discussed, then see if it has been found impossible to operate under full load using a clean oil of 70 viscosity at 100 deg. fahr.
24	Increases wear of pistons and cylinders and causes engine to pump oil, thus accumulating carbon	No answer	No definite rule for changing. Depends on what examination shows	Yes. Tests on trucks equipped with hot-air stoves, rings and pistons of different design, and a system of steam cooling so that one could have benefit of observations based on the performance of a number of trucks	No answer
25	No answer	Variable factor; believes 15 per cent for new engines and 25 per cent for old engines	No answer	Yes. Better distribution, vaporization and better starting devices	No answer
26	Increases wear in bearings and cylinders if excessive. A 10-per cent dilution will not show any marked tendency if viscosity of oil is high	No answer	Depends on the operator	No answer	No answer

Statements of engineers representing 26 manufacturers of automobiles and engines are presented in this table in condensed form without comment or alteration of the sense intended. See p. 117 for summary.

Exhaust-Valves and Guides for Aircraft Engines

By S. D. HERON[1]

Illustrated with DRAWINGS AND PHOTOGRAPHS

[C 54 The Society shall not be responsible for statements or opinions advanced in papers or in discussions at its meetings]

THE investigation of valve-cooling and of valve and guide wear was initiated on account of exhaust-valve trouble with the type-J air-cooled cylinder. This cylinder has a 5⅝-in. bore, a 6½-in. stroke, a 2¼-in. diameter wide-seat tulip exhaust-valve with 9/16-in. lift, and a 2½-in. diameter tulip intake-valve also with 9/16-in. lift. It originally had a 7/16-in. diameter solid-stem tungsten-steel exhaust-valve, hard cast-iron guides and fixed rocker-tappets. The latter design is shown in Fig. 1.

In its original form, the type-J cylinder developed 48 b.hp. at 1650 r.p.m. Continual trouble with exhaust-valves and guides was experienced. The exhaust-valve stem at the junction of the stem and the neck was bright red, about 1300 deg. fahr., and invariably fractured there after a relatively short period of running, tungsten-steel valves lasting about 25 hr. and stainless-steel valves about 6 hr. Cast-iron exhaust-valve guides wore out in less than 10 hr. A file-hard tungsten-steel valve of the type shown in Fig. 2, having a 9/16-in. stem, but with a shallower hole and no filling, was then tried and eliminated breakage; at least, in a 50-hr. full-throttle test. It scaled, however, on the stem and the neck as the result of a temperature of approximately 1250 deg. fahr. In this test, a hard No. 3440 S. A. E. Steel valve-guide was used, proving much superior to cast iron, but wearing considerably at the valve-tip end on account of side-thrust and slightly at the head end because of the scale on the valve-stem. The left view in Fig. 3 shows the valve after the 50-hr. run.

A file-hard tungsten-steel valve of exactly the type shown in Fig. 2 was then tested with salt, using a hard tungsten-steel guide. The valve-cooling was much improved. The stem was dead-black and the hot zone, although reaching a temperature of approximately 1100 deg. fahr., was much reduced in area, being about ¾ in. wide and confined to the neck midway between the inner edge of the seat and the junction of the stem with the neck. After 100 hr. of full-throttle running, the last 50 hr. being under conditions of violent auto-ignition without attention, scaling of the neck was evident, but very little was observed on the stem. The view at the right of Fig. 3 shows the condition of the valve at the conclusion of the run. Wear of the valve-stem and of the hard tungsten-steel guide was found. This was definitely due to the solid tappet, as later tests in which the rocker fulcrum was altered to a more favorable position relative to the valve-tip did not greatly reduce the wear of the guide, valve-stem, tip and tappet. Substitution of a roller tappet, as shown in Fig. 4, finally eliminated the wear of all these parts. Consequently, they will now stand a 100-hr. full-throttle test at 1800 r.p.m. without measurable wear. Tests on this cylinder, when fitted with a case-hardened inlet-valve, showed that extreme hardness is of advantage even for inlet-valves.

Much work has been done on the Type-K air-cooled cylinder. This cylinder is of 4½-in. bore by 5½-in. stroke and has a 1⅞-in. diameter tulip inlet-valve and a 1 13/16-in. diameter tulip exhaust-valve, both with ½-in. lift. Fig. 5 illustrates the complete cylinder; Fig. 6 a section of its exhaust-port. Tests were carried out with a cylinder which, except that it has a cast-iron head and the bronze valve-seat inserts and spark-plug bushings are omitted, is exactly like the one shown in Fig. 5. This cylinder developed 140 lb. per sq. in. brake mean effective pressure or 27.8 b.hp. at 1800 r.p.m., the temperature of the head wall at a point on the exhaust-valve seat reaching 750 deg. fahr. and even higher. Despite this very high head-temperature, excellent cooling was obtained with a salt-cooled valve, the hottest zone on the valve being in the middle of the neck, about ⅜ in. wide, and just perceptibly red, approximately 900 deg. fahr. With an unfilled valve identical in design with the one shown in Fig. 6, the valve-cooling was by no means so good; the red zone began about ⅜ in. from the inner edge of the seat and extended over all the visible portion of the stem, the maximum temperature of 1300 to 1350 deg. fahr. occurring at the junction of the stem and the neck. While so high a temperature is undesirable, the design was partly responsible; improved results could no doubt have been obtained in this case with a valve designed to be used without internal cooling. Notwithstanding, the cooling was better than that obtaining in some water-cooled aircraft-engines now in use. These tests indicate that cylinder temperature has far less influence on valve-cooling than is commonly supposed and that the major factors in valve-cooling are the design of the valve, valve-port, valve-seat, guide and guide-boss.

It is notable in these tests that, in spite of the high temperature of the exhaust-valve seat in the cylinder, the exhaust-valve rim was black, less than 900 deg. fahr., in all tests, showing that a high rate of heat-transfer from valve to cylinder is possible where the temperature difference of the portions in contact is less than 150 deg. fahr.

At the conclusion of the above-mentioned tests, all fins were removed from the head and the barrel of the cylinder, and a water-jacket was welded into place. No difference in performance, 27.8 b.hp. or 140 lb. per sq. in. brake mean effective pressure at 1800 r.p.m., was obtained, but the valve-cooling was improved. A salt-cooled valve ran dead-black under all conditions, while with the uncooled valve previously used, a red zone about ⅜ in. wide having a temperature about 1100 deg. fahr. was evident at the junction of the stem and the neck.

In the judgment of several observers, the cast-iron type-K cylinder, in air-cooled form with a salt-cooled valve or in water-cooled form with either type of valve, exhibited the most efficient valve-cooling yet seen at the Division in any cylinder.

[1] S.M.S.A.E.—Aeronautical mechanical engineer, engineering division, Air Service, McCook Field, Dayton, Ohio.

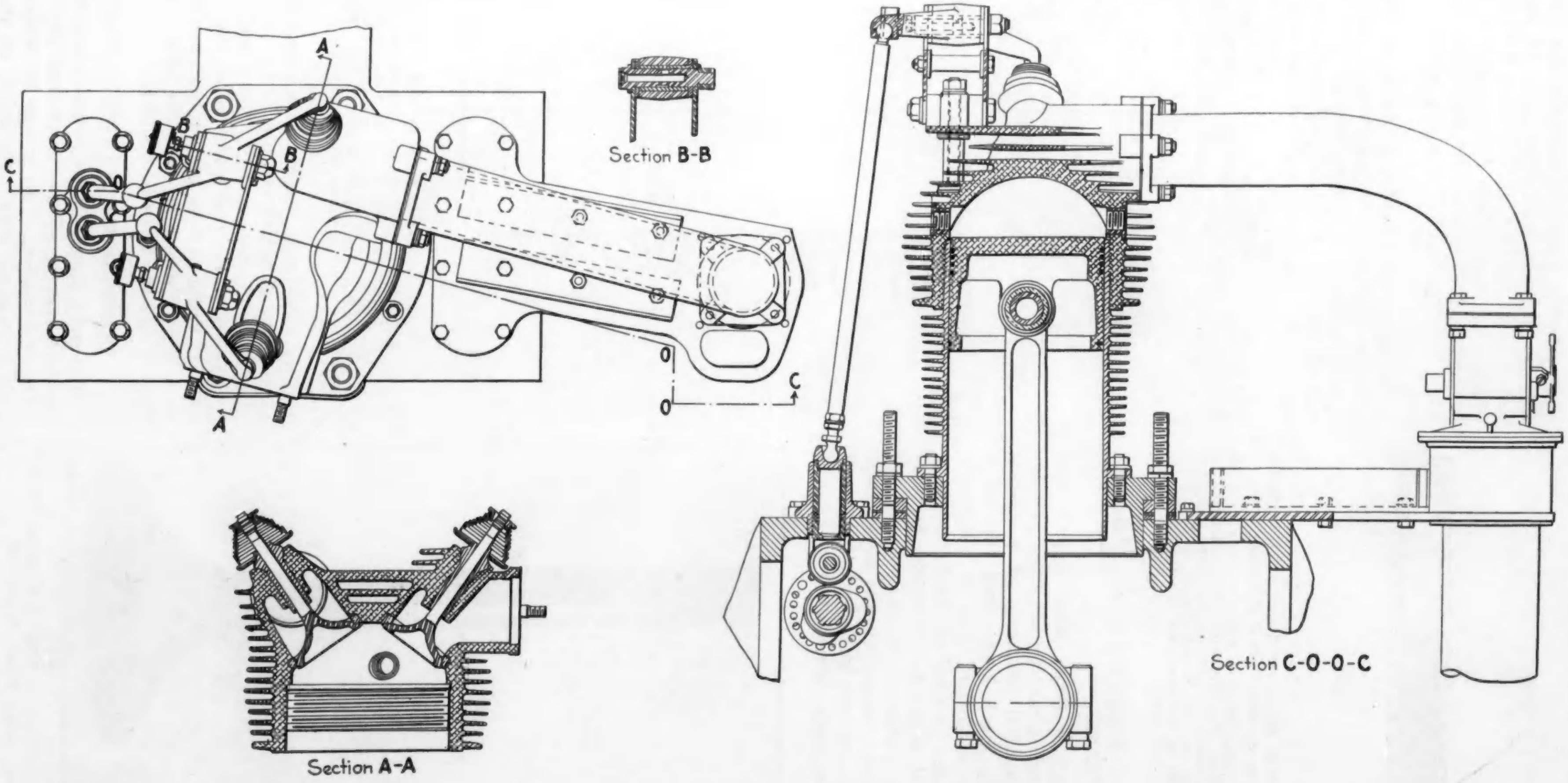

FIG. 1—ORIGINAL FORM OF THE TYPE J AIR-COOLED CYLINDER DEVELOPED BY THE ENGINEERING DIVISION OF THE AIR SERVICE

This Cylinder Has a 5⅝-In. Bore and 6½-In. Stroke and Developed 48 B.Hp. at 1650 R.P.M. Continual Trouble with the $\frac{7}{16}$-In. Solid-Stem Tungsten-Steel Exhaust-Valve and the Hard Cast-Iron Guides Led to the Investigation of the Subjects of Valve Cooling and Valve and Guide Wear Reported in This Article

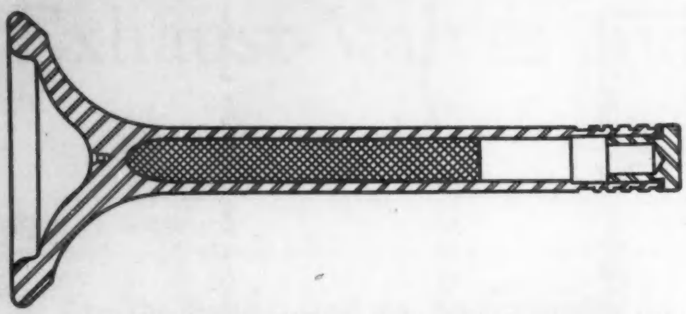

FIG. 2—THE INTERNALLY COOLED EXHAUST-VALVE WITH A $\frac{9}{16}$-IN. STEM THAT WAS TRIED IN THE TYPE J CYLINDER

This Tungsten-Steel Exhaust-Valve With a Shallow Hole and No Filling Was Tried in an Effort To Eliminate Breakage at the Junction of the Stem and the Neck. No Fractures Were Reported in a 50-Hr. Full-Throttle Test, but the Valve Scaled on the Stem and the Neck as a Result of a Temperature of Approximately 1250 Deg. Fahr.

HORSEPOWER AND BRAKE MEAN EFFECTIVE PRESSURE FIGURES

Single-cylinder test-engines fitted with Type-J and Type-K cylinders were used in making the tests just described. Since the mechanical efficiency of a single-cylinder engine is usually much lower than that of a multi-cylinder engine, a condition that is extremely marked in testing a cylinder as small as the Type-K, the actual brake-horsepower obtained does not correctly represent the severity of duty sustained by an exhaust-valve or by the cylinder generally. Therefore, the horsepower and brake mean effective pressures quoted were obtained by adding to the observed brake-horsepower and brake mean effective pressure, corrected for barometer, the difference between the friction loss of the single-cylinder test-engine and that of a modern first-class aircraft engine. The friction-loss figures used in making this adjustment were obtained by motoring the respective engines, while at normal working temperature, by an electric dynamometer.

On the single-cylinder test-engine, the friction mean effective pressure at normal revolutions per minute of the Type-J cylinder is approximately 25.0 lb. per sq. in.; that of the Type-K cylinder is approximately 32.5 lb. per sq. in. A modern aircraft engine within the range of 1650 to 1800 r.p.m., which is the range considered in this report, has a friction mean effective pressure of approximately 15 lb. per sq. in. Therefore, in the corrected brake-horsepower and brake mean effective pressure figures, 10.0 and 17.5 lb. per sq. in. mean effective pressure were added, respectively, to the observed outputs of the Type-J and the Type-K cylinders.

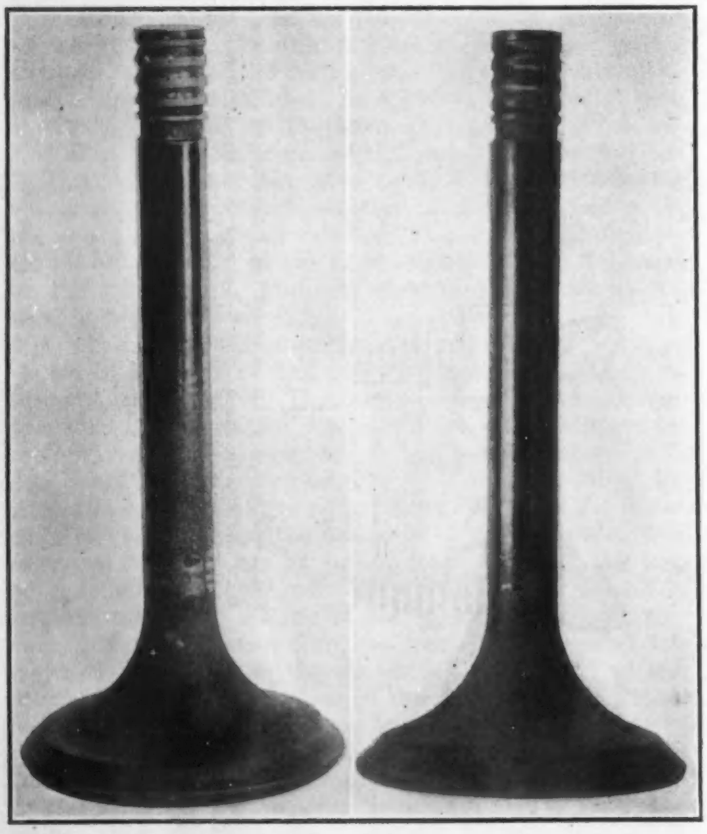

FIG. 3—CONDITION OF EXHAUST-VALVES USED WITH THE TYPE J CYLINDER AFTER TEST RUNS WERE COMPLETED

The Photograph at the Left Is of an Unfilled Valve of the Type Illustrated in Fig. 2 after a 50-Hr. Test. The Valve at the Right Was Run at Full Throttle for 100 Hr. the Latter Half of Which Was Mainly under Conditions of Violent Auto-Ignition, without Any Attention. Salt Cooling Was Used and While Scaling of the Neck Was Evident, Very Little Was Observed on the Stem

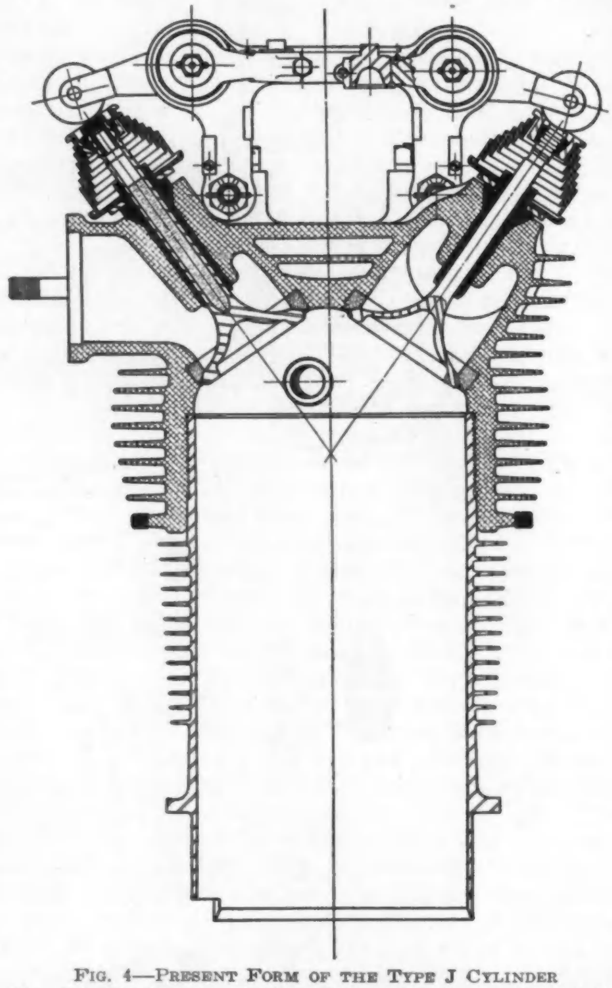

FIG. 4—PRESENT FORM OF THE TYPE J CYLINDER

The Substitution of a Roller Tappet for the Original Solid Design Eliminated the Wear of the Guide, the Valve-Stem, the Tip and the Tappet Found in Earlier Tests. The Cylinders Will Now Stand a 100-Hr. Full-Throttle Test at 1800 R.P.M. without Measurable Wear

CONSIDERATION OF INTERNAL VALVE-COOLING

The main purpose of internal valve-cooling is to reduce the temperature of the valve-head and of the head end of the valve-stem. This is done by reducing the temperature differences within the valve, or, in other words, by reducing the temperature of the head and increasing that of the tip end of the stem. In the stem a reduction of the maximum temperature and of the temperature

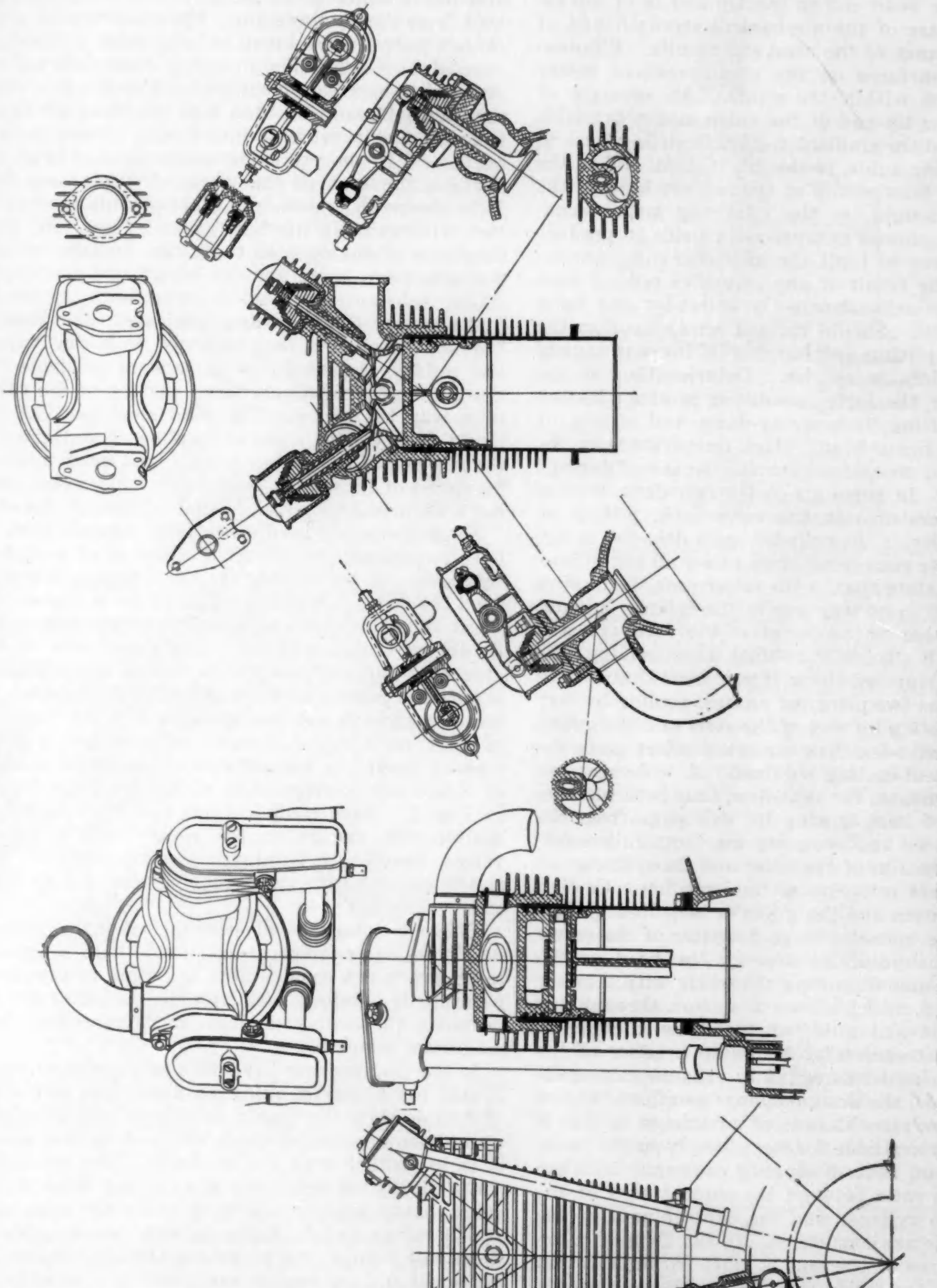

FIG. 5—THE TYPE K ENGINEERING DIVISION AIR-COOLED CYLINDERS

This Cylinder Has a 4½-In. Bore, a 5½-In. Stroke and a 1⅞-In. Inlet-Valve and a 1 13/16-In. Exhaust-Valve, Both of the Tulip Type with a ½-In Lift. On a Test a Cylinder of This Type Fitted with a Cast-Iron Head and Having the Bronze Valve-Seat Inserts and the Spark-Plug Bushings Omitted Developed 27.8 B.Hp. at 1800 R.P.M. In This Test the Temperature of the Head Wall on the Exhaust-Valve Seat Reached 750 Deg. Fahr. and Even Higher. Despite This High Head-Temperature Excellent Cooling Was Obtained with a Salt-Cooled Valve, the Hottest Zone on the Valve Being in the Middle of the Neck and about ⅜ In. Wide and Having a Temperature of Approximately 900 Deg. Fahr.

gradient from the head end to the tip end is of advantage, as an increase of the mechanical strength and of the fatigue resistance of the head end results. Elimination of red-hot surfaces on the stem produces better bearing conditions within the guide. An increase of temperature at the tip end of the valve makes available a greater temperature-gradient for transmitting heat to the outer end of the guide, to the oil, if used, and to the cooling-medium. Elimination of the red-hot head of the valve should be sought, as the relatively large incandescent area of a normal exhaust-valve tends to produce detonation and thus to limit the available compression-ratio. Usually, the result of any extensive red-hot area in the head of an exhaust-valve is to render the valve generally unreliable. Should the red zone extend to the rim of the valve, pitting and burning of its seat usually develop very rapidly in service. Deterioration of the valve itself under the latter condition is often accompanied by the cutting, hammering-down and pitting of the seat in the cylinder-head. High temperature in the valve neck does not necessarily involve danger of damage to the valve-seat. In some air-cooled cylinders, despite fairly high temperatures in the valve neck, pitting or burning of the valve or the cylinder seats does not occur, the rim of the valve remaining black under all conditions. It may be well to state that in the latter case the cooling of the valve rim is in no way due to the cylinder's being air-cooled, but rather to the design of the valve rim and seat; in fact, with efficiently applied water-cooling, the conditions at the rim and the seat are somewhat better.

Valve-cooling has two principal phases: cooling by way of the seat and cooling by way of the stem and the guide. The width of a valve-seat has a marked effect upon the efficiency of the seat-cooling obtained. A wide seat enlarges the area available for heat-flow, thus both increasing the amount of heat flowing by this path from the valve to the cylinder and reducing the temperature-difference between the rim of the valve and the cylinder, on account of the lower intensity of the heat-flow. Cooling by means of the stem and the guide is benefited by several design factors, namely: large diameter of the valve-stem, bringing the guide as close to the head of the valves as possible and shrouding the guide with a heavy guide-boss. Fig. 6, which shows a section through the exhaust-valve, port and guide of the Type-K cylinder, illustrates the most successful designing practice of the Engineering Division with regard to exhaust-valve cooling. It embodies all the design factors mentioned above. The large-diameter valve-stem is of advantage in that it increases the area available for heat-flow from the stem. The possibilities of heat dissipation through the stem are evident if the ratio between the contact area of the valve-seat and the cylinder and the contact area of the stem and the guide are considered. In the Type-K cylinder, the contact area of the seat is 1.075 sq. in. and that of the stem with the guide is 4.570 sq. in., a ratio of 4.25 to 1; and this takes no account of the further stem-cooling that is due to the tip's being sprayed with oil. In the Type-J cylinder, the seat area is 1.67 sq. in. and the stem area is 5.47 sq. in., a ratio of 3.27 to 1. These two ratios show that, if suitable means be used to conduct heat up the stem and maintain a more or less uniform temperature-distribution throughout its length, much more heat can be dissipated by the stem than by the seat. While the contact between the stem and the guide is less intimate than that between the valve-seat and the cylinder, the latter contact is maintained for only two-thirds of the cycle, approximately; during the remaining third, the valve-seat and the cylinder are not only out of contact, but the valve rim is rapidly receiving heat from the outgoing gas. The effectiveness of thermal contact between the stem and the guide is markedly increased by the oil-film resulting from lubrication, for, although it is a poor conductor, oil produces a much better thermal condition than that produced by dry metal-to-metal contact with its intervening air-gap between the surfaces. In the preceding calculations of stem contact-surface, the area of the whole circumference is given. It is theoretically possible to obtain this amount of contact with running fits but, nevertheless, with the small clearance of the stem in the guide rendered possible by the salt-cooled valve and the hard valve-guide, this condition substantially obtains even without lubrication. Some present designs using lubricated valve-stems would function much less satisfactorily with dry valve-stems and guides. Internal cooling renders available for heat dissipation the relatively large surface of the valve-stem in a way that no possible solid stem can. A body of liquid in a violent state of turbulence contained within the interior of the valve conducts heat much more rapidly by virtue of its motion than can a solid metal stem having a cross-section equal to that of the column of liquid.

Some previously used methods of internal valve-cooling have relied upon the direct dissipation of heat from the valve-stem to the outside air by a finned valve-stem beyond the guide. A design of this type is shown in Fig. 7 which illustrates a water-cooled valve applied to an R. A. E. 4E air-cooled cylinder. The experience of the Engineering Division has shown that so elaborate a design is entirely unnecessary for efficient internal-cooling. Internal cooling is not considered worth the complications of split valve-guides, forked valve-rockers and the increased headroom necessitated by added valve-length, all of which are introduced in a design of the type shown in Fig. 7. Such complications result in unsatisfactory design with regard to the rocker side-thrust on the valves, practically eliminating any possibility of completely enclosing the valve-guide, spring, rocker and push-rod.

Efficient internal valve-cooling sharply reduces the maximum valve-temperature. And there is good reason to believe that a considerable reduction in the mean temperature is obtained, although this is not of marked importance, the main consideration being reduction of the maximum temperature.

In the Engineering Division's salt-cooled valve, cooling is obtained by partly filling a hollow valve with a mixture of fusible salts that has a boiling or decomposing point well above any temperature attained by the valve when it is in contact with the mixture. This method avoids the difficulty of retaining the cooling fluid within the valve that is experienced in this Country with mercury-cooled valves and in England with water-cooled valves. With salt fillings, the pressures attained in the interior are small and are readily contained by a drive-fit plug in the tip of the stem. The final seal by welding, required with valves in which the cooling is produced by the boiling and the condensing of a fluid, is in this case unnecessary.

With mercury or with water-cooled valves, cooling is obtained by the enclosing in the stem of a small quantity of fluid, which is boiled at the head end and condensed at the tip end. To work most efficiently, this type of valve should have a vertical stem and its head should be down. Otherwise, if the stem be far out of the vertical, the boiler and the condenser action will fail. Although the cooling of valves filled with fluids vaporizing at working temperature is due mainly to boiling and condensing,

under certain conditions a considerable amount of cooling seems to be obtained by the turbulent motion of the filling. There is reason to believe that the equality of valve-cooling between the top and the bottom cylinders experienced with mercury-cooled exhaust-valves in some air-cooled radial engines is as much due to the turbulent motion of the mercury as it is to the boiling and the condensing, for about 60 per cent of the stem volume is filled with mercury, which is in excess of the amount required for boiling and condensing only. The valves in the lower cylinders obviously would fail to cool by the latter method if they were filled with only sufficient fluid for this purpose, as the fluid would be in the condenser and the vapor in the boiler.

The internal pressure produced by the boiling of mercury or of water causes much trouble from leakage. The mercury-cooled valve has never been dependable, for it is by no means unusual to find after some hours of service that a considerable portion of the mercury has leaked out of the stem. With water-cooled valves, great difficulty has been experienced with leakage, and also with the high internal-pressure's either swelling or bursting the valve-stem. A typical failure due to the latter cause is shown in Fig. 8. It is not surprising that troubles with bursting are experienced, as temperatures in excess of 700 deg. fahr. have been measured on both the head and the tip of such valves. At this temperature, saturated steam develops a pressure of approximately 3000 lb. per sq. in. As such a pressure sets up considerable additional stress in the metal of the valve, the difficulty of containing it by welding or other means is obvious.

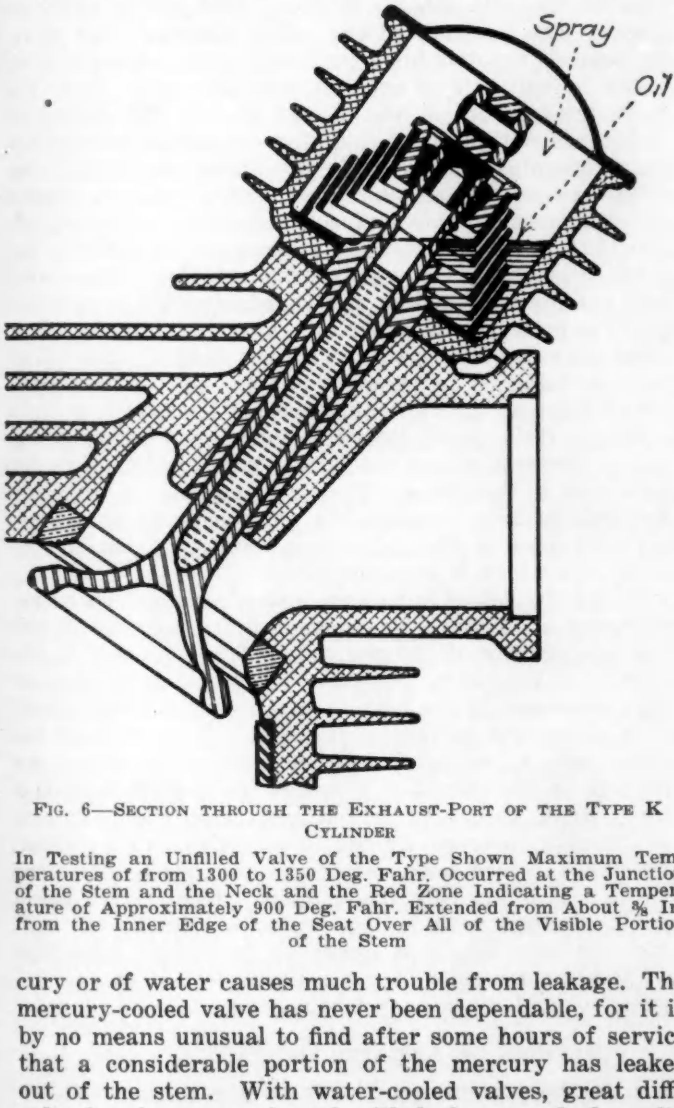

Fig. 6—Section through the Exhaust-Port of the Type K Cylinder

In Testing an Unfilled Valve of the Type Shown Maximum Temperatures of from 1300 to 1350 Deg. Fahr. Occurred at the Junction of the Stem and the Neck and the Red Zone Indicating a Temperature of Approximately 900 Deg. Fahr. Extended from About ⅝ In. from the Inner Edge of the Seat Over All of the Visible Portion of the Stem

The Engineering Division's salt-cooled valve does not depend for its cooling upon boiling and condensing, but rather, as stated previously, upon the heat-transfer resulting from the turbulent motion of a non-boiling liquid contained within the interior. The valve is so filled with salt that a space of from ⅝ to 3 in. or more is left between the top of the molten salt, at the assumed working temperature of 750 deg. fahr., and the inside end of the valve-stem tip-plug. The existence of a high degree of turbulence in the filling, due to the motion of the valve, has been experimentally determined by the following method. A glass tube partly filled with mercury was attached to the push-rod of an air-cooled cylinder; the engine was then motored and the state of the mercury examined by an oscilloscope, the flashing-light type of stroboscope. At 1800 r.p.m., or 900 complete oscillations of the push-rod per min., the mercury formed a turbulent rain of particles, completely filling the 2-in. space between its upper surface and the upper end of the glass tube. The turbulence was approximately as violent during the stationary periods of the push-rod as it was

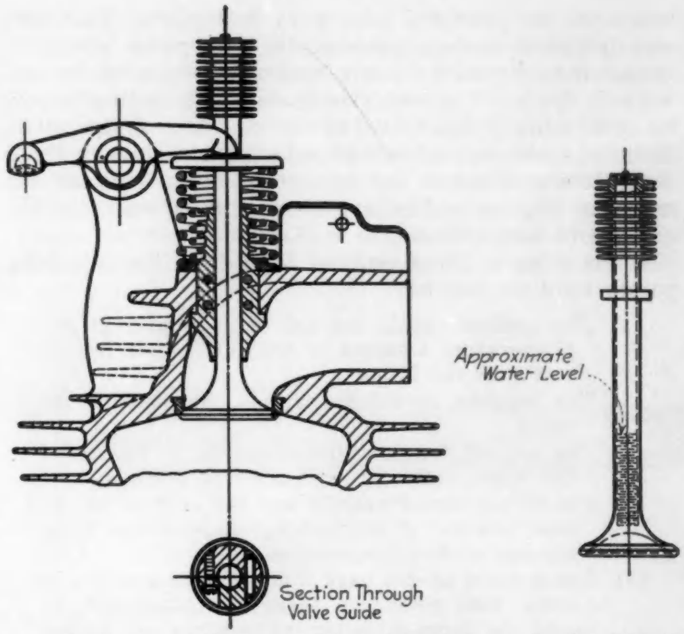

Fig. 7—Application of a Water-Cooled Valve to an R.A.E. 4E Air-Cooled Cylinder

In This Method of Internal Valve-Cooling Reliance Is Placed upon the Direct Dissipation of Heat from the Valve-Stem to the Outside Air by Employing a Valve-Stem That Is Finned beyond the Guide. In the Opinion of the Engineering Division Such an Elaborate Design That Required the Introduction of Such Complications as Split Valve-Guides, Forked Valve Rockers and Increased Headroom as a Result of the Increased Valve-Length Is Entirely Unnecessary for Efficient Internal-Cooling

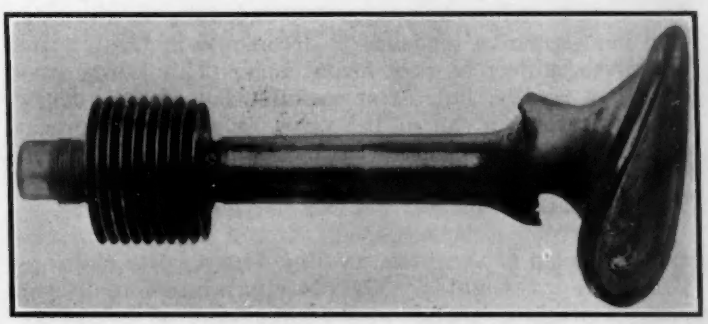

Fig. 8—A Typical Case of Water-Cooled Exhaust-Valve Failure

In This R.A.E. 21 T Water-Cooled Exhaust-Valve, the Stem Broke as a Result of the Excessive Internal Pressure Produced as a Result of the High Operating-Temperature. Temperatures in Excess of 700 Deg. Fahr. Have Been Measured on Both the Head and the Tip of Such Valves and at This Temperature Saturated Steam Develops a Pressure of Approximately 3000 Lb. per Sq. In., Which Sets-Up Considerable Additional Stress in the Metal of the Valve

when the rod and the tube were in motion. This test was initiated to determine whether the valve might be expected to function equally well with the head up and with it down. The result indicates that cooling should be practically independent of the position of the valve. Tests of three sets of salt-cooled exhaust-valves in three Engineering Division R-1 air-cooled radial engines did not show any inequality in valve-cooling between the top and the bottom cylinders.

In choosing a filling-medium for valves, the following points were considered:

(1) The medium should not boil or decompose at any temperature attained by the valve when in contact with the filling

(2) The medium should not attack the steel of the valve

(3) The melting temperature should be as far below the mean working-temperature as possible

(4) The filling should readily wet the surface of the steel interior at all working-temperatures without any surface preparation

(5) The medium should have a low specific-gravity, in order that relatively large quantities can be used in large-diameter valve-stems or hollow valve-heads without appreciably increasing the total weight of the valve

(6) The filling should be cheap and plentiful

(7) The filling should not be dangerous to handle, so that it can be readily inserted by unskilled labor

(8) When the filling, in the frozen state, is rapidly and locally heated, it should exert but a relatively small bursting force on the container

With mercury valves, the inside of the valve-stem at the head end, that is, the boiler section, must be plated with mercury-tin or some other amalgam in order that the mercury shall wet the surface. This seems to be a rather difficult and uncertain process, as a considerable percentage is rejected on account of incomplete plating. Tests of mercury-filled valves lacking any surface preparation to insure wetting showed little or no additional cooling due to the filling, thus demonstrating the importance of the property of wetting the interior surface of the valve.

Pure tin, the first filling tested by the Engineering Division, gave satisfactory cooling but so eroded the interior of the stem at the head end that a fracture resulted.

The filling that has been most used is the eutectic mixture of sodium and potassium nitrates, which has 45.5 per cent of sodium nitrate and 54.5 per cent of potassium nitrate by weight[2]. This mixture melts at 425 deg. fahr. and, from the melting-point to 750 deg. fahr., expands approximately 16 per cent. It readily wets the surface of hot steel, up to 900 deg. fahr. at any rate, and has shown no tendency to decompose in the interior of valves subject to very heavy duty. This filling gave excellent results, but, after examination of the temper colors on the tip end of the valve, it was thought that the melting temperature was too high and that the salt was frozen in the tip of the stem, thus markedly reducing the heat dissipated from this portion of the valve.

To overcome this supposedly frozen condition of the salt in the tip of the stem, a filling with a lower melting-point was investigated. The eutectic mixture of 34 per cent of lithium nitrate and 66 per cent of potassium nitrate by weight[2] melts at 265 deg. fahr. but is very hygroscopic, making it necessary to heat the mixture to at least 750 deg. fahr. to get rid of the water. When heated to 800 deg. fahr. in an open steel crucible, it shows a tendency to bubble and blow off the surface of the container, a tendency thought to be due to decomposition. It is likely, however, that this does not occur when the mixture is under pressure. Comparative tests of identical valves filled with sodium-potassium nitrates and lithium-potassium nitrates in the Engineering Division Type-J and Type-K cylinders showed no advantage or disadvantage in cooling when the latter filling was used.

To secure the maximum heat-dissipation from the tip of the stem, the filling at that point must obviously be in a liquid condition, the conductivity of frozen salt being low. When the tip of the valve is sprayed with relatively cool oil and when, moreover, the cross-sectional area of the salt column is small, the salt is likely to freeze. The tendency of the salt to freeze in the valve-tip depends not only upon the temperature of the cooling media to which it is exposed, but also upon, first, the mean temperature of the filling; second, the degree of turbulence within the filling, for turbulence diminishes the temperature gradients in the filling; and, third, the ratio between the cross-sectional area of the salt column and the area of the surface extracting heat from it. Provided the valve motion is constant, turbulence depends mainly upon the percentage of the valve cavity that is filled with molten salt. Reducing the proportion of filling increases the turbulence but has its limits. For, when the valve is operating with the head up, the filling must be sufficient in quantity to come into contact with the portions of the valve that are hot enough to initiate melting. Both direct internal cooling of the valve-head and an increase of the valve-stem bore tend to transfer more heat to the filling. The latter method of attacking the problem also increases the ratio between the cross-sectional area of the salt column and the area of the surface to which it transfers heat.

Filling the valves is an easy and commercial operation conducted as follows. The valve is first immersed in salt at a temperature of 750 deg. fahr. When the salt in the interior is quiescent, the valve is placed on a rack or ledge immersed in the bath so that its tip projects about ½ in. above the surface of the salt. Then, to eject the excess salt, a rod approximately 1/64 in. smaller than the hole in the valve-tip is pushed in until it strikes a stop. Next, the valve is removed from the bath and the tip-plug inserted, driven in slightly with a mallet, and finally forced home with an arbor press while the salt in the interior is still molten. Then, after being rapidly washed with boiling water to remove the salt from the exterior, it is quenched in linseed oil. The last treatment results in a gun-barrel finish coated with drying-oil and gives considerable protection in storage.

Methods of Applying Internal Cooling

Up to the present, practically all the work with salt-cooling has been done with salt contained within the valve-stem only. If a suitable size of valve-stem is used, this is without question all that is required to secure practically dead-black valves in a cylinder having an output of 30 b.hp. or less per valve.

Investigation with valves having both the head and the stem filled with salt is now in progress. For outputs of 60 to 70 b.hp. per valve, it is certain that direct cooling of the valve-head will be necessary to secure results similar to those obtained with smaller valves. With internal cooling applied to the stem only, the flow of heat from the head to the stem is to a considerable extent along rather than through the metal of the valve-head.

[2] See Inorganic and Theoretical Chemistry, by J. W. Mellor, vol. 2, p. 812.

With the filling uniformly in contact with all parts of the valve, the limitations imposed by heat-flow along the metal of the head are eliminated, and heat is freely transferred from the valve to the filling, and vice versa, in all portions of the valve.

In the Type-K cylinder, Figs. 5 and 6, a valve 1 13/16 in. in diameter without head cooling, using a stem of ½-in. outside diameter and a 21/64-in. hole, has proved very satisfactory, as, under all conditions, an almost black or a dead-black condition was obtainable. The top diameter of the cylinder-seat used with this valve is 2 1/16 in., the seat width is 0.177 in., the seat-contact area is 1.075 sq. in., and the stem-contact area is 4.570 sq. in. In order that a valve of this size may be used without lubrication of the stem and the guide, that is, without oil-cooling, a 9/16-in. stem is recommended.

In the Type-J cylinder, Fig. 4, up to an output of 49 b.hp., a valve with stem-cooling only has proved satisfactory. This valve, shown in Fig. 2, is 2¼ in. in diameter and has a 9/16-in. hollow stem with a 25/64-in. hole. The top diameter of the cylinder-seat is 2 9/16 in.; the width of the seat, 0.221 in.; the seat-contact area, 1.670 sq. in.; and the stem-contact area, 5.470 sq. in. The type of valve shown in Fig. 9 has a ⅝-in. stem and a stem-contact surface of 6.45 sq. in., the seat surface remaining unchanged. For comparative purposes, details of the Liberty valve are of interest. The diameter of the valve is 2½ in., the top diameter of the cylinder-seat is 2.716 in. and the width of the seat is 0.125 in. The stem is solid and of 7/16-in. diameter. The contact area of the seat is 1.023 sq. in. and that of the stem 4.680 sq. in. Thus the contact areas of the Liberty cylinder with its 2½ in. valve are practically no greater than those of the Type-K cylinder with its 1 13/16-in. valve. It is, however, not surprising that the valve-cooling of the Liberty cylinder is so much inferior to that of the water-cooled Type-K cylinder.

For an output of 52.5 b.hp. the valve shown in Fig. 2, proved to have insufficient cooling to prevent scaling. Red scale was produced on the neck, particles of which became detached and adhered to the seat of the valve. Although the stem of the valve was dead-black, a layer of black oxide formed at the junction of the stem and the neck and resulted in poor bearing conditions at the mouth of the head end of the guide. Tests of valves with direct head-cooling were therefore carried out. Two valves of the type shown in Fig. 2 were modified by drilling the hole in the stem through to the head cavity and welding a steel plate to the rim, as shown in the top view in Fig. 9. Both valves showed considerable improvement in cooling and, in preliminary tests, ran dead-black, but leaked salt into the cylinder within a few hours running because of porous welding. The welds in the two valves had successfully resisted a gasoline-pressure test of 200 lb. per sq. in. both before and after treatment. The leakage in service was probably caused by the solvent or fluxing action of the salt upon occluded particles of oxide. Any weld, therefore, must be practically free from occluded oxide particles; butt-welding seems, then, to be the most nearly certain method. As the salt conducts the major portion of the heat to be dissipated, the design shown in this view is needlessly heavy in both the neck and the rim. The use of a flat plate to close the head cavity is uneconomical because the plate must be heavy to resist the explosion pressure. A dished plate, two alternative designs of which are shown in the two central drawings, is a more suitable form. The design in the upper view subjects the weld to compression rather than to tension, contains the largest amount of filling, probably an excessive quantity, and approaches a more nearly stream-line form than any valve at present used in high-speed engines. Both designs are to be tested shortly.

If hollow-head valves are to be used, it will be necessary to secure absolute reliability in any welds that are exposed to explosion pressure. Otherwise the design with stem-cooling only is preferable, there being practically no risk from leakage of the filling with this type. If a welded hollow-head is to be used, possibly the valve

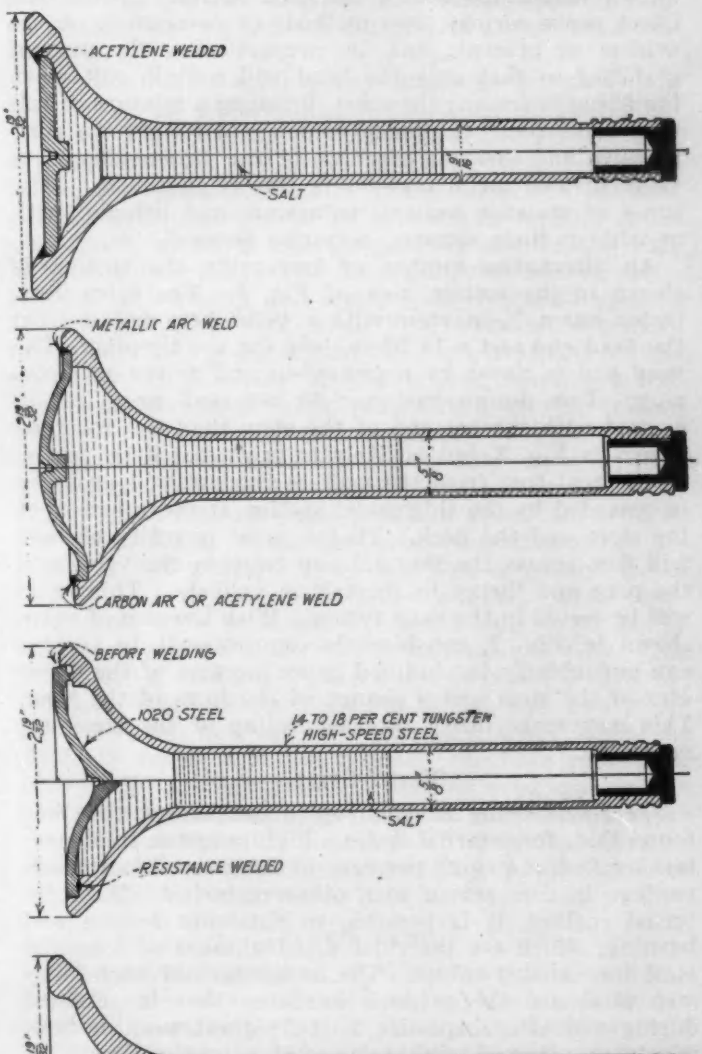

FIG. 9—FOUR FORMS OF EXHAUST-VALVE FOR THE TYPE J CYLINDER
In the Valve Illustrated at the Top the Head Is Hollow and a Flat Head-Plate Is Attached to the Rim by the Oxyacetylene Process. A Dished Head-Plate That Is Attached by the Metallic Arc and the Carbon Arc or Acetylene Welding Processes Is Shown in the View Immediately Below. This Form of Plate Subjects the Weld to Compression Rather than Tension, Contains a Large Amount of Filling and Approaches a More Nearly Streamline Form than Any Valve Used at Present in High-Speed Engines. The Lower Central View Shows a Butt-Welded Concave Head-Plate That Is Attached by the Resistance Welding Process. An Alternative Method of Increasing the Cooling Is Shown at the Bottom. This Valve Has a ⅝-In. Stem with a ½-In. Hole Drilled from the Head and a 13/32-In. Hole for the Tip Plug. The Head End Is Closed by a Ground-In and Driven-In Taper Plug. While This Design Has Over 60 Per Cent More Salt in Contact with the Hot End of the Stem than the Valve Shown in Fig. 2, It Is Likely To Prove but Little Better, as the Heat Flow from the Neck to the Salt Will Probably Be Retarded by the Thin-Metal Section at the Junction of the Stem and the Neck

can be designed so that the weld will be exposed to the internal-pressure of the salt and to exhaust pressure only.

It is possible that trouble may arise with the hollow-head type of valve, owing to the excessive fluid-pressure set up within the head upon starting the engine. In a valve having its head down, when the engine is rapidly opened up to full-throttle position from cold, the filling in the head melts and tries to expand while that in the stem is still frozen, thus causing a liquid pressure of unknown magnitude within the head cavity. Should this effect prove serious, two methods of overcoming it are evident at present: one, by proportioning the amount of filling so that only the head will contain salt when the filling is frozen; the other, by using a mixture of salt with some inert substance, which will reduce the compressive and shearing strength of the frozen filling. A finely divided metal may fulfill this requirement. Mixtures of metallic sodium, potassium and lithium, with or without their nitrates, may also be used.

An alternative method of increasing the cooling is shown in the bottom view of Fig. 9. The valve illustrated has a 5/8-in. stem with a 1/2-in. hole drilled from the head end and a 13/32-in. hole for the tip-plug. The head end is closed by a ground-in and driven-in taper-plug. This design has over 60 per cent more salt in contact with the hot end of the stem than has the type shown in Fig. 2, but is likely to prove but little better, as the heat-flow from the neck to the salt will probably be retarded by the thin metal section at the junction of the stem and the neck. That a great quantity of heat will flow across the thermal gap between the valve and the plug and thence to the salt is unlikely. This valve will be tested in the near future. With the size of valve shown in Fig. 2, considerable improvement in cooling can undoubtedly be obtained by an increase of the diameter of the stem and a change of the form of the head. This may make direct internal-cooling of the head unnecessary.

Valve Steels

The Engineering Division up to the present time has found that, for internal cooling, high-tungsten steel, containing from 14 to 18 per cent of tungsten, has the advantage in comparison with other materials. With internal cooling, it is possible to eliminate scaling and burning, which are the chief disadvantages of tungsten steel for exhaust-valves. The advantages of high-tungsten steel are the extreme hardness that is retained during and after exposure to the highest working-temperatures attained with salt-cooled valves, strength at high temperatures and excellent resistance to wear. Strength at high temperature has little advantage with internal cooling; thus, hardness and resistance to wear are the two important considerations. Practically file-hard valve-stems that will not soften in service allow the use of file-hard valve-guides, the advantages of which will be discussed later.

A valve steel that could be produced with non-scaling properties in conjunction with secondary hardness or, at any rate, practically file-hardness, after tempering at 750 deg. fahr., the filling and approximate running temperature, would be superior to tungsten steel for internally cooled exhaust-valves in cases where the maximum temperature of the valve exceeds 900 deg. fahr. The Engineering Division is investigating the problem of procuring such a steel.

The best method of attacking the exhaust-valve problem, however, appears to be by reducing the temperature to such a point that scaling will not occur with any steel. The excellence of modern valve-steels has considerably obscured the exhaust-valve problem, instead of eliminating the cause of the trouble, that is, excessive temperature.

A temporary cure has been obtained by improving the properties of the valve material at high temperature. Such an expedient in no way eliminates the fundamental cause, and recurring trouble is experienced with every increase of valve size and duty.

The Attacking of Valve Material by Nitrate Fillings

The possible occurrence of nitrogenization of the valve steel with nitrate fillings has been investigated by the materials section of the Engineering Division. An 18 per cent tungsten-steel exhaust-valve that had run 100 hr. at full-throttle in a Type-J cylinder, the last 50 hr. mostly with violent auto-ignition, was sectioned and examined. The microstructure of the head end of the stem, the hottest portion and that most likely to be attacked, revealed no evidence whatever of nitride structure.

Description of Failures Occurring with Salt-Cooled Valves

A variety of valve failures occurred during the development of the salt-cooled valve. They are listed below:

(1) Loss of salt from a valve of the type shown in Fig. 2, due to a loosened tip-plug and to the salt, the lithium-potassium nitrate mixture in this case not being completely dehydrated before insertion. Only a small quantity escaped before the loss was detected and the valve removed. No case of leakage of sodium-potassium nitrate occurred with this type of valve

(2) Leakage of sodium-potassium nitrate into the cylinder from two valves of the type shown in the top view of Fig. 9, due to porous welding

(3) Loosening of the tip-plug in two valves of the type shown in Fig. 6. Although the plugs loosened sufficiently to drop out when the valve was inverted, no salt leakage could be detected. The loosening occurred with short solid plugs. These plugs have since been made hollow to conform to the shape of the hole in the valve-tip, if oval, and lengthened in order to increase the hold of the valve on the plug

(4) In one of the valves mentioned in the preceding paragraph, the loose plug was replaced. The second plug had an excessive amount of drive, 0.005 in., in the valve-tip; as a result, the stem split later throughout its length, while in service. This failure was detected by the valve's sticking in the guide

Form of Valve-Head

The Engineering Division has reason to consider, in general, that the tulip type of valve is superior to the flat-head or mushroom type as regards cooling, gas-passing capacity and resistance to warping and stretching. These conclusions have, as a whole, been corroborated by the Bureau of Aeronautics, of the Navy Department, after much comparative testing of Liberty engines, and by the Wright Aeronautical Corporation, which has carried out extensive tests on Wright E and H engines. Recent full-throttle tests of Liberty engines at the Engineering Division have sharply demonstrated that the tulip form of valve has greater reliability and strength than has the mushroom type.

Valve-Guides

The problems of wear and scoring of the valve-stem and the valve-guide seem to be worthy of much investi-

gation. Examination of the valves and the guides from service engines after normal use has shown that, even when lubricated, normally 10 per cent of the stems and the guides are scored by the time the first overhaul becomes necessary. The obvious line of attack is to increase the hardness of the wearing surfaces; and this has in practice proved to be one successful method of solving the difficulty.

File-hard tungsten-steel salt-cooled valves are now on test with both file-hard tungsten-steel and case-hardened low-carbon-steel guides. The tungsten-steel guide is probably the best general solution of the valve-guide problem; for, although it is not quite so hard initially as the case-hardened guide, it is less likely to lose its hardness in service on account of cylinder temperature, removal or insertion by a blow-pipe, in aluminum cylinders, or any heat-treatment that is likely to be given to the cylinder-head during the assembling and the enamelling.

The case-hardened guide gives excellent service where conditions do not cause loss of hardness at the valve-tip end. But when practically the whole of the guide is contained within the guide-boss of an air-cooled cylinder, the entire guide becomes partly softened. In water-cooled cylinders, and in air-cooled cylinders, when a considerable portion of the top end of the guide protrudes from the boss and is thus directly air-cooled, or when the guide is lubricated and thus oil-cooled, the loss of hardness at the valve-tip end of the guide is inappreciable. Drawing of the valve-head end of the guide occurs more or less in any case, but in practice it is of no consequence, as little or no wear occurs at this point, and, unless the valve-stem scales on account of excessive temperature, galling of the hard valve-stem does not occur. Extreme hardness of the valve-tip end of the guide is required to resist the side-thrust occurring with rocker-operated valves. Wear of the valve-stem and of the guide due to side-thrust and the resultant tilt of the stem in the guide first occur on a line at the mouth of the guide and over a length of the stem. Line contact of the stem at the mouth of the guide ceases as soon as wear takes place. It is largely this line-contact that results in the cutting and the galling of soft valve-stems; the greater the clearance between the stem and the guide and the shorter the guide, in terms of the number of valve-stem diameter lengths, the greater will be the tendency to tilt and to cause cutting and galling.

Few aircraft valve-gears entirely eliminate side-thrust on the valve-stem. Thus, when the relatively difficult bearing conditions of an exhaust-valve stem are considered, it is obvious why a hard valve-stem and guide are desirable. Even in cases where side-thrust on the valve-stems is entirely eliminated, scoring of the guide and the stem, particularly at the head end, occurs with soft valves and cast-iron guides. Rotation of the valve distributes the wear equally around the circumference of the stem and reduces or eliminates pitting of the valve-seat in the cylinder. Rotation can be produced by the volute ribbon type of valve-spring used on the Engineering Division air-cooled cylinders.

There is little question that a roller instead of a solid tappet on the end of the valve-rocker, where it bears on the valve-tip, has considerable effect in reducing side-thrust, thus reducing the wear of the valve-stem and the guide. That the roller is of value is shown by its rapid rotation, apart from the observed reduction in wear. The larger the roller, within limits, the greater is its effect. Lubrication is of similar value. Neither of these devices, however, suffices to prevent scoring and wear with soft steel valves and cast-iron guides. The Type-K cylinder at first had soft stainless-steel valves and hard cast-iron guides. Despite a roller on the rocker end and ample lubrication, valve-stem scoring and guide wear of both the inlet and the exhaust-valves could not be obviated. An internally cooled valve of stainless steel that had been quenched and only drawn at 750 deg. fahr. by the operation of filling with salt gave much better results than the soft stainless-steel valves, showing only very slight scoring, but was inferior to a hard tungsten-steel valve.

The arguments against the tungsten-steel guide are the cost of the material and the difficulty of machining. To ream a hole so free from scratches and grooves that lapping-out 0.001 in. after hardening will produce a mirror-like finish is difficult. If the surface in the bore before hardening is such as to preclude lapping for a final finish, grinding must be resorted to. This is both difficult and expensive with the small bores used in valve-guides. If reaming and lapping are depended upon, a badly reamed hole will result in a waste of expensive material. It is possible that the heat-treatment of the bar-stock might reduce the difficulty of reaming a hole free from scratches. The possibilities of rifle-drilling followed by broaching, as a commercial method of producing a smooth finish requiring only lapping after hardening, are being investigated.

The case-hardened guide produced from No. 1015 or No. 1020 S.A.E. Steel has many manufacturing advantages. If a poorly machined hole is produced, the cost of the scrapped material is negligible. After heat-treatment, it is necessary to remove only 0.001 in. by lapping to produce a mirror-like finish in the bore. The Engineering Division's practice is to ream 0.0005 in., nominal, under standard size, to harden and then to lap to 0.0005 in., nominal, over standard size. When the guide is driven into the cylinder, the bore returns to practically standard size. Case-hardened guides are given a case-hardening 3/64 to 1/16 in. deep, a practice that is in accord with that of the Engineering Division in connection with wearing parts subject to heavy loads in air-cooled cylinders.

Valve Size

For air-cooled cylinders, the Engineering Division successfully uses valves of relatively smaller diameter, but with considerably higher lift, than are current practice in this Country. A comparison of Liberty and Type-J Engineering Division cylinders shows the different types of practice. The Liberty is of 5-in. bore and 7-in. stroke, has a capacity of 137.5 cu. in., runs normally at 1700 r.p.m., and has two $2\frac{1}{2}$ in. valves. The exhaust-valve has a $\frac{3}{8}$-in. and the intake-valve a 7/16-in. lift. The Type-J cylinder is of $5\frac{5}{8}$-in. bore and $6\frac{1}{2}$-in. stroke, has a capacity of 161.5 cu. in., runs at a normal speed of 1800 r.p.m., and has a $2\frac{1}{2}$ in. intake valve and a $2\frac{1}{4}$ in. exhaust-valve, both with 9/16-in. lift. The mean effective pressure of the Type-J cylinder is not inferior to that of the Liberty engine when both are tested as single cylinders; in fact, few cylinders with appreciably higher mean effective pressures than that of the Type-J engine when so tested are known.

The practice of using exhaust-valves of a diameter smaller than that of the intake-valves has much in its favor and appears to be free from undesirable effects on performance. Tests[8] on a four-valve aircraft-engine cylinder showed that, at moderate speeds, reducing the

[8] See The Journal, April, 1922, p. 257.

area of the exhaust opening to less than one-half that of the intake has a surprisingly small effect upon performance. This is readily explained by the fact that it is desirable to use the minimum pressure-drop through the valve to secure induction, whereas any pressure up to 100 lb. per sq. in. is available for the purpose of expulsion and can be used without deleterious effect.

Reduction of the exhaust-valve size to the minimum compatible with the maximum performance is to be sought, since it facilitates valve-cooling; however, if carried to excess, as in the tests previously quoted,[3] the effect is to increase valve-cooling difficulties. Reduction of the size of both the intake and the exhaust-valves to the minimum allowable renders the design of the cylinder more flexible and, in general, tends to produce a combustion-chamber that is more compact, easier to cool and more rigid and thus less liable to distort and to cause uneven valve seating.

Reduction of valve size to the minimum can, to a considerable extent, be secured by the use of relatively high lifts. The effect of lift upon the gas-passing capacity of poppet valves has been investigated by the National Advisory Committee for Aeronautics,[4] the results showing the marked advantage of high lift.

Lifts as high as 5/8 in. cause no great difficulty in aircraft engines up to a speed of 1800 r.p.m., even with large valves having push-rod operation. With a lift of this order, the design of the cams, valve-springs and gear requires more attention than if only 3/8 to 7/16-in. lift were used.

For air-cooled aircraft-engines of present speeds of revolution, the Engineering Division has reason to favor the high-lift valve of the minimum diameter.

General Conclusions on Valves and Guides

The foregoing report may appear to deal with elaborate and costly constructions, but this is more apparent than real. The general conclusions arrived at as a result of the investigation are as follows:

(1) Reduction of valve temperature eliminates valve breakage, burning and scaling, and allows the use of relatively large exhaust-valves with entire safety. The elimination of incandescent surfaces within the combustion-chamber allows increased compression-ratio and fuel-economy. Internal exhaust-valve cooling renders possible a large two-valve cylinder, which, according to the recent experience of the Engineering Division, seems to be more desirable than the four-valve type, especially for medium-speed aircraft-engines. Even if the two-valve type does give a slightly lower output than the four-valve type gives, it still remains more suitable for many service aircraft-engines on account of the reduced complication and expense both in manufacture and overhaul. The large two-valve cylinder in practice seems to be the equal of the four-valve type in output and fuel economy, and to be superior to it as regards reliability, particularly for speeds up to 1800 r.p.m. The viewpoint of the Engineering Division may well be covered by stating that, if a 60-b.hp. air-cooled cylinder to run up to 2000 r.p.m. were required, a two-valve type would unquestionably be produced

(2) Salt-cooled hard valves with hard guides, while undoubtedly somewhat more costly than those of the normal type, are much cheaper in the long run, the cost of a set of valves and guides initially being a minor item compared with that of removing an engine from an airplane for overhauling, or that of frequent replacements. However, they reduce the cost in the first place, if their use allows a reduction from four to two valves. From the recent experience of the Engineering Division, it seems that a valve and guide combination capable of 500 hr. of full-throttle running without attention of any sort is only a matter of a relatively small amount of further research

(3) The cooled hard valve with a hard valve-guide allows a material reduction in the clearance necessary between the stem and the guide, thus improving the heat-transfer from the valve and reducing the seat-wear in the cylinder on account of less valve-tilt at the moment of seating or unseating. It has proved to be possible to run with as little as 0.0035-in. clearance on a 9/16-in. stem in a Type-J cylinder. If the wear occurs with hard stems and guides, it is productive of polished and not torn rough surfaces; thus, the cause of almost all valve-sticking is eliminated

(4) Hard valves so far have proved to be immune from pitting. Any pitting that may occur is invariably to be found in the valve-seat in the cylinder; such pitting in well-cooled engines is apparently always due to hammered-in oil-carbon. Rotation of the valve tends to suppress pitting due to the latter cause

(5) In relatively large cylinders, the exhaust-valves may be made at least 10 per cent smaller than the intake-valves without any undesirable effect on performance. The effect of such a reduction in diameter is to render the problem of valve-cooling simpler and to allow more compact, more rigid and more easily cooled cylinder-heads

[4] See National Advisory Committee for Aeronautics Report No. 24.

DAIRY PRODUCTS

The Department of Agriculture gives the aggregate value of dairy products in the country in 1921 as $2,400,000,000, which was more than three times the value of the wheat crop of that year, and it has been increasing each year since. The official agricultural publication of Wisconsin is authority for the statement that one-half of the farm income of that State is from dairy products and probably that is true of other States.

In nearly all States an increased production of dairy products is being urged. Particularly is this true in the West, where freight charges to market on bulky products are an important percentage of the prices; and the question is often asked whether this prevailing tendency is not to be viewed with misgiving, as perhaps leading to over-development in that line. There is such danger in every movement where the economic inducements are so pronounced as in this case and where the movement is so widely fostered and encouraged. The dairy industry, however, always has been comparatively stable, and of course cannot be rapidly expanded like hog-production, the record of which in the last year has a tendency to make farmers cautious about wholesale shifts from one line of production to another. The increase in milk cows has been very regular in the past; from 17,136,000 head in 1900 to 20,625,000 in 1910, to 23,722,000 in 1920, and on Jan. 1, 1924, as officially estimated, to 24,675,000. No doubt the increase might be more rapid, for a great many dairy calves are slaughtered for veal, but several years would have to pass before any noticeable effect upon production would occur. The consumption of dairy products, particularly of ice cream and condensed and powdered milk, is increasing per capita, but in the United States is on the whole considerably below that of most European countries which make a much more extended use of them.—National City Bank.

Commercial Aviation in 1923

By EDWARD P. WARNER[1] METROPOLITAN SECTION PAPER

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THE discussion of this paper, as printed herewith, is that presented at the Metropolitan Section Meeting held on Nov. 15, 1923, after the delivery of the paper; it includes written contributions by members and remarks made at the meeting. An abstract of the paper, as then delivered, precedes the text. A reference is given to the issue of THE JOURNAL in which the paper was printed, so that members who desire to refer to the complete text as originally printed can do so with a minimum of effort.

ABSTRACT

A COMPARISON of the air-maps of the world for 1920 and 1923 shows that the principal change that has taken place during this period has been the consolidation of numerous short airlines into long ones. The saying that airlines of greater length than from 250 to 350 miles cannot be operated successfully still holds good, but the trend has been toward connecting or combining several routes of this length into one of much greater length. Most terminals are so far from the centers of the cities served by them that much valuable time is lost in going to and from the flying-fields, the average speed of the journey being correspondingly reduced. In Europe most of the airlines have been made international for political reasons and because of the saving of time that would ordinarily be lost at the customs frontiers. On the lines between England and the Continent in 1920 approximately 50 per cent of the passengers were Americans. On many other lines the passenger traffic was almost negligible, the lines being able to operate only because they were subsidized by their respective governments.

Recent technical developments abroad have been slight, the principal ones having reference largely to the comfort and the convenience of passengers; those in America have been marked by the extensive use of the seaplane for transporting both passengers and express. Advances in this Country have been due mainly to the successful operation of the Air Mail Service, which has made a remarkable record for efficiency in all sorts of weather and under adverse conditions. But although the service has been most efficient there have been but few passengers. This has been attributed to the cost and to the irregularity of the service, but these reasons are shown to carry little weight.

Although statistics show that a fatality occurs in the ratio of 1 to every 1,250,000 passenger-miles flown, which would indicate that the odds are 2 to 1 against its occurring in a machine flying 12,000 miles per year for 40 years, there is an instinctive feeling of danger in the minds of the public. Persons are free to admit that aviation is the coming means of transportation for others but not for themselves. This feeling is enhanced by newspaper stories of the thrills and the suffering of pilots who have attempted to break records and by descriptions of the stunts performed in exhibition flying. Safety is more important to most persons than thrills.

European methods of impressing passengers with the extra-hazardous nature of the venture and of disclaiming responsibility for accidents do not tend toward making riding in airplanes more attractive. Foreign companies are independent because of subsidies and do not encourage passenger traffic. Subsidies are unfortunate in many ways because of the obligations that are required in return and because of the restrictions that are imposed, which retard proper development.

Bulk of traffic inspires confidence; the rails of a railroad are a constant reminder of stability. The trips of an airplane, on the other hand, do not give an impression of continuity of service.

Large-scale operation cannot be secured until the necessary money can be obtained to finance it and, in turn, the requisite amount of money cannot be obtained until the financial interests are convinced by the volume of traffic that the venture will be successful. The most obvious method of increasing the confidence of the public would be through extensions of the Air Mail Service. It is suggested that a large number of lines should be installed and radiate from a single city rather than be spread over large sections of country. After stability has been thoroughly well demonstrated and volume of traffic has been secured in one locality, the service should be extended to other sections.

Two recommendations are made for obtaining greater confidence: (*a*) that those interested in commercial flying devote themselves to a study of public psychology and (*b*) that a display of energy, vision and courage on their own part would undoubtedly lead to the expenditure of the money necessary to lay a firm foundation for a profitable structure. [Printed in the April, 1924, issue of THE JOURNAL.]

THE DISCUSSION

ALEXANDER KLEMIN:—It is possible that airlines would come into being more readily in the United States if the geographical conditions were as favorable as they are in the case of the London to Amsterdam airline, where a couple of hours by air are balanced against an all-night or an all-day sea journey in a possibly very rough sea. If lines radiating from our greatest center, New York City, are considered, it will be found that, so long as flying is only by day, no advantage really accrues in using the airplane at all to cities like Chicago or Buffalo, in view of the wonderful train service available. A man would have to start very early in the morning indeed to reach Chicago earlier than does the Twentieth Century Limited. And there is certainly no object in going to Buffalo by air if flying is possible only in the daytime. Until night-flying is continuously possible, we can only consider exceptionally favorable runs, such as perhaps Detroit to Cleveland, or Havana to Key West.

Instead of trying to force public confidence by statistics and huge enterprises, is it not best to run mail and express lines only at first, and let public confidence come naturally? The possibility of real express and mail service with night and day runs should, it seems to me, be thoroughly exploited first and passenger carrying left until later.

W. B. STOUT:—The dollar sign is still the foundation of all business. Any movement that is not self-support-

[1] M.S.A.E.—Associate professor of aeronautical engineering, Massachusetts Institute of Technology, Cambridge, Mass.

ing, and does not give promise of being so, is a charity. Until aviation is weened away from its present means of sustenance and learns to exist on what it gets for itself, it will never grow beyond its present infant stage. Aviation is not a new industry; it started almost simultaneously with the commercial automobile industry; yet, so far, it has not arrived anywhere. I know of no company that is making airplanes pay.

It is impossible to make present American types of airplanes pay a dividend on any scale that is attractive to investors; and, after all, this is the foundation of business. No man is interested in a transportation system that is losing money, unless he can see a way of making it earn money. The first requirement in this case is a commercial airplane.

If all the world were a landing-field; if fogs or rain did not exist and we had blue sky and sunshine 24 hr. of the day, with perfect weather; if every conceivable law regarding the control of aircraft that could be devised by legal minds behind an office desk were on the books at the City of Washington, these would not create one commercial air-vehicle. All the concrete roads in the world did not create one automobile; but many automobiles forced good roads. The only thing that will bring commercial aviation is a commercial airplane.

If we take example from other transportation systems, a commercial airplane will have to do differently than present airplanes do. We must be able to change the powerplants as a train changes locomotives. All moving parts must be capable of being instantly inspected. All structural parts possible should be in duplicate, so that no single piece can break and let you down. The airplane must be able to operate from 6 to 20 hr. per day in the air, for on this percentage of time in the air depends the entire earning capacity of the unit.

An airplane should carry the maximum load for one pilot and for the horsepower of the engine. With full load it should be able to climb at least 6 deg. Although its maximum-load capacity will depend entirely on the service in which it is to be used, in airline work it should carry roughly a load of 1 ton. The design should have around it servicing mechanism and devices to assure absolute safety and certainty of operation, keeping always in mind the fact that safety is the first fundamental of profit. Provision for night-flying should be standard equipment.

Once we have a commercial air-unit, the next problem is the developing of a business and a financial plan around the airplanes that will enable one to finance the building of them. The ingenuity of this plan is just as important as that of the design itself. Following this must come a complete operating system, also carefully thought out and developed, as well as hundreds of other items, part of them determined by business conditions and others by the terrain over which the line is to run.

It must not be forgotten that a projected proposition must be able to pay its way safely with things as they are, not as we wish them to be, or expect them to be a few years hence. No matter when we start an airline, "today" is the starting-point and the conditions of that day must be met. The first airlines, for this reason, will be by no means what we like to visualize as the eventual lines, but the possibility is here right now of a really fat profit from just an ordinarily good commercial airplane that can be kept in the air many hours per day. Looking to government subsidy for this work is a delusion, for special privileges never have worked and never will. It is time that commercial men, other than engineers, should get together and devise a plan for taking present known facts, not opinions, and translating them into dollars.

I realize that this discussion is dealing in generalities, but that is the entire extent of America's aviation industry. Until someone takes it out of the stage of generalities and applies a few facts, commercial aviation will not come to our shores.

From the passenger's standpoint I thoroughly agree with Professor Warner's paper; but if the freight possibilities in certain localities in America are studied, where railroad service is almost nil and where communities are ready to guarantee full loads for as many trips as can be made per day, it will be found that immediate real material is there to be transported immediately, while the general public is becoming convinced.

The Aeromarine Airways line, operating from Detroit to Cleveland, proved particularly this year that passengers were willing to fly and pay a real price to fly between those cities. It also proved that the war-type airplane of 5 years ago makes about as good a commercial airplane as a curved dash Oldsmobile would make a 1-ton truck. With proper equipment, this line would pay a handsome profit even in passenger work, although the freight business between these points is far more important to the industries of the two cities and is much easier to obtain.

M. Holland:—I concur in the opinion of Professor Warner that the only way to demonstrate the practical value of a commercial aeronautic enterprise is by actual operation, carried out in such a manner that its safety, regularity and efficiency will be brought to the attention of the persons who might be prospective patrons. In analyzing the choice of air-routes and their development in Europe and the Far East, it may be that the unprofitable maintenance of the lines during peacetime may be justified by their tactical value for military purposes.

Regarding the causes of the slow development of commercial aeronautics and the antipathy of the general public toward this method of transport, it is my impression that too much of a step was attempted at one time; enthusiastic optimists began throwing networks of ethereal airlines all over the maps of the United States and Europe without proper recognition of the necessity for a careful analysis of the necessary adjuncts to the successful operation of an airline, namely, such things as traffic analysis, ground organization, operating personnel, topographical and meteorological considerations and the design of proper equipment.

In connection with the antipathy of the public to the use of commercial air-transport, I have a keen appreciation of the detrimental effect in the public mind of the scare-head accounts of airplane accidents as a deterrent to development. It has been my opinion, however, that the reason the outstanding accomplishments of aeronautics, particularly those of a semi-statistical nature, have been dealt with so sparingly by city editors and even minor accidents to airplanes have called for front-page notices, is that the latter have a news value which the former lack. To check this impression, I discussed it with several editors of the metropolitan "dailies" over the telephone, and my opinion was verified; although the editors were in general strongly of the opinion that the accomplishments of and favorable comment on aeronautics generally had been in excess of unfavorable comment in the newspapers, they did not deny that the business of a newspaper is to cater to the masses and that a dramatic story of an airplane accident is of considerably more news value to the man in the street than uninteresting statistics or records of accomplishments, unless such

accomplishments are of a spectacular nature, such as the breaking of the world's altitude records and feats of speed-kings of the air.

For instance, I was agreeably surprised to learn from a former associate of mine, Lieutenant Van Zandt, who has been detailed from the engineering division of the Air Service to the office of the Chief of Air Service to make a detailed analysis of meteorological factors in the operation of commercial airways, analysis of traffic conditions and various studies in connection with the ground organizations necessary for the successful conduct of an air-route, that, in a very recent report of the Interstate Commerce Commission covering a comprehensive analysis of the reliability of maintaining a schedule of all the trains operating in New York State for the last 3 years compared with the operating schedule of the Air Mail Service, at 75 m.p.h., the percentages of arrivals and departures on time in the Air Mail Service was higher than that of the train schedules, and at 80 m.p.h. the record of efficiency was slightly lowered.

You can well imagine that, to the layman, this bit of news tucked away in the corner of the metropolitan dailies, would receive scant notice. The comparison of the news value of the dramatic and ofttimes fatal events in connection with airplane accidents and those accounts of specific accomplishment was humorously illustrated in a talk at the Dayton Engineers' Club by Charles F. Kettering, president of the General Motors Research Corporation, in which he said that in one year, in one county of Missouri, 64 people were killed by being kicked by mules, which was considerably in excess of the number of fatalities in the total aeronautical activities of the United States during the same period. It is to be noted, however, that all were notified through the headlines of the daily newspapers of the fatalities by airplanes, whereas news of the fatalities through association with mules, even in a State where it is reputed "the people have to be shown," was tucked away in a voluminous report, issued from some Government agency.

With reference to the phase of Professor Warner's paper that deals with Government subsidy, I can say that personally I am not in favor of this method of fostering the development of commercial aeronautics. Private capital has built up all the great modern industries and enterprises of today, notwithstanding the fact that in the early days of the railroads it was necessary to secure the largest portion of that capital from England. Accounts appear in the papers every day of capitalists seeking outlets for their funds in foreign projects in every corner of the earth. These projects are in many cases proved by the previous success and potential money-earning capacity of similar projects in the same field. It is obvious, therefore, that the financiers have not been convinced that a commercial-aviation project is a sound investment.

I feel that I can speak freely on this particular point as I have had some experience, and I might conclude by saying that the typical attitude of the capitalist is that "he must be shown" that any successful commercial aviation project has

(1) A real demand for service
(2) The sound management of experienced business men
(3) Operating personnel of most reliable character
(4) Proper equipment

R. H. Upson:—Two things that Americans are supposed to possess are progressiveness and ingenuity, but one of their characteristic shortcomings, at least in the eyes of Europeans, is a certain lack of patience. They want to build up a big business over-night; they are not willing to wait a year or so, if necessary.

Taking as an example another type of transportation, the only organized means of communication between a suburb of Detroit and the city for some time was an electric interurban railway. Suddenly one day a line of motorbuses appeared on the scene. Were they immediately filled with passengers? No; the street-cars were crowded to the doors, but the motorbuses went back and forth with plenty of empty seats. Time after time a motorbus would go by persons waiting for a car. They would not try to stop it; they would probably give you a very plausible reason, but what do reasons amount to? The real reason was simply human inertia.

Perhaps you think I am contradicting myself, but I am not. Average persons will always have inertia about things that they do not know about, whether they live in America, England or any other place. Those of us who are trying to promote the use of aircraft must recognize that. Do not try to rush them too much. They are coming. Let them come. In the meantime, the time will not be wasted; we can use it to good advantage.

In particular, we can improve the aircraft themselves. Much can be done in developing engines to make them thoroughly economical and reliable. We can make numerous improvements in the way of economy, comfort, convenience, steadiness, safety, carrying capacity, particularly for mail and express, and last, but certainly not least, the ability to fly consistently and safely at night.

The reason I am bringing up all these things is that they react again on the same old problem of getting people's confidence; and to get that will be a rather slow process. Newspaper publicity will help. Talking about it ourselves will help; but, after all, the thing that will "sell" aviation is a few adventurous spirits who get into the machine and ride. You must sell them so thoroughly on the fundamental economy and advantages of the new means of transportation that they will talk to their friends; by ordinary human contact, the news will spread from mouth to mouth, and pretty soon aviation will "go over the top" in fine shape.

C. F. Redden:—I should like to comment on Mr. Stout's discussion. One point is glaring and to it you can trace most of the handicaps that we have had to hurdle in commercial aviation. Many persons who start a commercial airline begin on the basis that an airplane, a barrel of gasoline and a monkey-wrench make an airline. They do not; not even the beginning of one. The one thing that will "put aviation over" is confidence, and the only thing that will establish "confidence" is an organization of men who have operated airplanes day after day over a set route and have made good. All the publicity, pictures and conversation in the world on commercial aeronautics will not hit the bull's-eye until people see airplanes leaving one point and arriving at another on schedule time or on successful flights day after day. They note that, and note it very quickly.

The perfect airplane will come as the perfect automobile came. No engineer in the world could have imagined 15 or 18 years ago what we have designed today. Who have perfected it? The boys that lie on their backs under the cars in the garages all over the Country. Operating men and operating organizations will perfect the airplane; there is no doubt about that.

An illustration of how people acquire confidence is afforded by our operations between Detroit and Cleveland last year. We sold over the counter, like cigars or

steamship tickets, $15,000 worth of transportation to persons who came and bought it without argument and without button-holing. That is more than twice what we sold the year before by button-holing and urging them to fly. Why did they do it? Because last year we left Cleveland and Detroit 272 times and arrived at our destination 272 times, a splendid demonstration of reliability. This year we had two forced landings, that is, two flights that we did not complete. One was due to fog that we encountered near Lorain. We took the passengers off in a launch; they sat perfectly contented and complained about getting out; they were having a good time and wanted to go on their way, but we felt that it was dangerous, owing to the fog. The other flight was delayed because of ignition trouble. We have crossed Lake Erie over 500 times in the last 2 years, and have carried upward of 4000 passengers without a single injury of any kind to anyone.

If our sales over the counter in Detroit next year do not double what they have been this year, we shall be reversing the law of gravitation, because we have seen this year, in a way that cannot be disputed, the fact that people there have caught the flying spirit. They want to fly and are willing to pay the price to fly.

We hear considerable comment that prices will have to be reduced. Our prices, like those of any pioneer organization, especially when pioneering is as expensive as it has been in this line, have been necessarily high. If the price year before last had been one-third of what it was, the number of passengers would not have increased very much, and the gross receipts would have been very much less. We reduced our price last year, and we hope to reduce it again this year. That is part of the evolution of the thing, along with more efficient airplanes that can accommodate more passengers.

We have just completed a metal flying-boat. If we had a fleet of them, we could fly at a very much reduced rate. The all-important point that all of us in the industry must emphasize is that the only way to sell flying to the public is to start, not with our thought concentrated on what type of aircraft we intend to use, but on what organization can do the trick. Until we get a group of men, of different temperaments, different ambitions and different degrees of skill all vibrating together and pulling together and singing the same song, we shall not have much commercial aviation. Once we get such an organization, improvements in the machines will follow rapidly.

A clear indication that this is a fact is afforded by the following: We have just completed 3½ years of service between Florida and points in the West Indies, the Bahamas, points on the Great Lakes and in and around New York City. We have flown more than 1,000,000 passenger-miles. We have carried over 26,000 paid passengers, over 30,000 passengers altogether, and have had only one serious accident. We have flown airplanes up and down the coast from New York City to Havana and back four times and have made two round-trips from Detroit to Havana, a total of 76,000 flying-miles. These included the trip of the Santa Maria a few years ago from Havana to New York City, to the Great Lakes and down the Mississippi River to New Orleans. When you consider that these flying-boats arrived in uncharted harbors, where the boys had never been before, to say nothing of the fact that they knew nothing whatever about the conditions in the harbors, that they took on fuel and went on their way, and that we have been repeating that performance year after year, it must be true that it is not the craft but the men that do the trick. It is the men that will make commercial aviation a success. Developing these organizations and supplying them with equipment such as the traffic demands will develop and boom aviation, and it seems to me to be the only thing that will develop and establish public confidence in flying.

We who are trying to get passengers and make the receipts match the expenditures of the business wonder why it is that people do not fly, why they hold back. It is not hard to understand, though, when one stops to think of it. You who were raised in small towns a generation or so ago will remember that when the circus came to town the big event of the day was the balloonist's getting out in the center of the field for the big balloon ascension. Some one connected with the circus, presumably his wife, would dress up a bundle of rags like a baby. The balloonist, before going up, would kiss his wife and the alleged baby goodbye, she would sob, and all that sort of thing. That was the biggest part of the show, and people would stand there wiping their eyes and crying in sympathy with the alleged heartbroken wife. That was the thought people would take home and the thing they would recall about going to the circus. The remembrance of that crazy loon going up in a balloon seemed to them nothing but sure suicide. That impression was drummed into the present generation. The coming generation is getting a different training.

All you will have to do to get people in this Country to support aircraft is, first, to get aircraft-operating organizations that know their business, and that will avoid foolishness and try to operate on a sane basis. I do not believe there is a community in the Country where it will not be possible to organize a successful commercial aviation company. I do not believe that the business has reached a point where it will not demand some support from the people for some time to come, either in the way of subsidies or in the form of advance sales of tickets that they obligate themselves to buy.

Flying is only a matter of confidence. It has been proved to be safe; and we have proved that it can be made to pay, because we have made certain parts of our operations pay in spite of the fact that we have had the expense of moving a fleet of flying-boats 3000 to 4000 miles twice a year, from Florida to our Northern operating bases and then back again in the fall.

AUGUSTUS POST:—I should like to endorse heartily what Mr. Redden has said about the making of men for aviation, and also to refer to the statement made by Mr. Uppercu that he started the Aeromarine Airways flying over water so that he would always have a safe landing-place to fly over. The subject that was assigned to me this evening is "Landing Places;" and undoubtedly this is the most important consideration that we have today.

I have devoted my attention during the last several years to reaching the Boy Scouts of America, some 610,000 of them, speaking to them in groups and out in the country, and also to other organizations, explaining the necessity for landing-fields, the assistance that can be rendered and the opportunities that aviation offers as a career for men in the future. We have assisted in establishing courses at New York University, in the college of engineering, for training aeronautical engineers.

A few days ago Sidney B. Veit, who has represented American aviation in Europe for the last 10 years, came from Paris. He said, "We always order our goods in Austria, or in the other parts of Europe, to be delivered by air. We wire in the afternoon of one day and we get the goods the next day. It would take 5 or 6 days for them

to come by rail and pass through the customs. We have been able in many cases to fill orders that we could not otherwise have hoped to fill because of lack of time." This merely shows that the business men of Europe are appreciating the value of time in transportation.

Men from the larger banking institutions of this city and of this Country, international bankers, like Dwight Morrow of J. P. Morgan & Co., Mortimer Schiff and John T. Pratt, are watching and waiting for the time when they can invest in aviation, and they all believe that that time is nearly here. It is necessary, of course, that facts and figures of actual accomplishment be shown. What Mr. Redden has told you of what the Airways company has done in the last few years, and what the Air-Mail is doing today, are the things that should be hammered into business men. They should have it explained to them that by night-flying they can extend the area of their business. Whereas a night trip is now a distance of 500 miles, the Air-Mail, flying at night, could go 1200 or 1500 miles; a letter mailed from New York City would reach cities on the Mississippi River, or farther West, in the same time that it now takes to reach Buffalo, Cleveland or Detroit.

When all the things that aviation can do are considered, it will be impossible for business men to get along much longer without its advantages. You could not cut off telephone or other facilities that you have in modern business, for you simply could not get on without them. The same thing will take place with the airplane. Commerce cannot afford to be without the service that it can render when mail and parcel-delivery time is cut down one-half. Though it may be a little more expensive, it will be more than worth the extra cost.

I have been interested in the subject for 20 years. The building up of landing-fields and the matter of night-flying now interest me particularly. Airplanes will take care of themselves. The engineers design and construct splendid machines today.

G. C. Loening:—Our own experience for 3 years has been largely along the line of furnishing private owners with aircraft that they can use. We have had three very successful years, particularly in the case of Commodore Vanderbilt of the New York Yacht Club, who has flown many thousand miles, and of several other owners who fly in such a way that they have neglected to look upon their flying experience as a novelty but are flying solely because they save so much time and have found in this vehicle so great a convenience that they are deriving a benefit from it and not merely a stunt. When one considers, in the case of some of these owners, for example, the very large amount of flying that is done with no publicity, the result is very beneficial, because to their friends they are actual users of aircraft, and seriously so.

In considering the question of the private ownership of airplanes, I think this meeting has entirely ignored so far one of its most important aspects. Anyone who was at St. Louis at the Air Meet could not have failed to be greatly impressed with some 110 or 115 privately owned airplanes that flew there from all parts of the United States. I do not believe that any country of Europe, or perhaps all the countries of Europe, could have got together so many privately owned airplanes as were flown out there by private owners. It is quite true that some of these were starving gipsy pilots; that the machines were old JN's and odd mixtures of JN's and Standards and Thomas Morses, but they were privately owned and they were flown there in civilian capacity. A large part of one corner of the St. Louis flying-field was covered for a distance of ½ mile with privately owned aircraft, which is a very splendid example of what may be expected in this Country if we get the proper start.

The fulfilment of the hope expressed by Professor Warner is certainly promised by the experiences that Mr. Redden has presented to us, which we all follow with such keen interest. Having had considerable experience with the difficulties of the business, I cannot help pointing out that perhaps the man that Professor Warner is looking for has been found in Mr. Uppercu, who has shown a persistence and a courage in this business that is truly remarkable.

To return to the question of publicity, and the point that was brought out and touched upon much too lightly for its magnitude, we see one of the ill effects in the 4 or 5 days' postponement of the Shenandoah's flight because of weather conditions. I have seen a great number of people who feel that lighter-than-air craft are failures because they cannot go out in unfavorable weather conditions. As a matter of fact, the delay was not entirely justified; but, because the Shenandoah is the only dirigible the Navy has, it naturally exercises an amount of caution that knows no limit; it must be very sure of its steps.

The fact remains that a weather limitation exists and, if at the very beginning of publicity of this sort, this fact is made known, it will be helpful. Publicity should have been given to the fact that in going to St. Louis and back the airship was blessed with a great amount of good luck as regards weather. If that had been emphasized at the beginning, the subsequent inability to go on a small trip to Boston, which would be nothing for a dirigible, and the fact that the trip had to be postponed for a week, would not have had the effect that it has had; the public would then have understood that this marvelous exploit was a piece of good luck, and that when we cannot quite make it we are in the normal status.

Given the time, the energy and the enterprise that we are bound to find in this Country, we shall overcome these difficulties. I assure you that we all, and particularly those who are intimately connected with aviation, are more impressed than ever with those 120-m.p.h. vehicles that can reach distances up to thousands of miles at three times railroad speed. That is a salable article and will be put over in this Country on a big scale.

Professor Warner touched on Government assistance in a manner that I do not agree with, because he contradicts himself in his own paper. He cited, as an example of commercial aviation that had succeeded, the Air-Mail, which is a Government-operated line. It is more so than any line in Europe, and today is the most successful demonstration of commercial aviation possible. Any feeling, therefore, that Government operation of aircraft must necessarily be inefficient and consequently unable to accomplish a result, I do not think can be dwelt upon as a conclusion at all. It depends entirely on how it is run. Certainly, if we had in this Country Government-operated airlines, in which expense was not considered but every regard was had for maintenance and equipment, operated in the way the Air-Mail is, we should have the opportunity of introducing to the American public, not the sensation of flying, but the enormous convenience, and the ability to "put one over" on your competitor by covering more ground and doing more business in a day than he can, because you spend less time waiting for railroad trains.

R. B. C. Noorduyn:—I think that Professor Warner, in touching on the question of subsidies, has touched on

the most unfortunate ones first. Perhaps what Mr. Loening has said has modified the general view of the assembly, which might have been turned against the idea of subsidies by some of the examples Professor Warner cited.

I know of one case where the subsidy is limited to two-thirds of the loss. That sounds very bad, to begin talking about the loss and to take it for granted that for a period of years there will be a loss; but in this particular case it has had the effect of encouraging the persons who originally financed the enterprise, which was in Holland, to go in for the purchase of new machines and for an extension of their operations, even to the extent of financing an experimental flight that is to be made next spring from Holland to the Dutch Indies, solely because the losses have not been so great as they originally anticipated they would be for the first few years. I think that is a case where the subsidy is working to quite good effect.

Some of the interests that financed that enterprise were the big oil companies, which probably considered it a duty to finance aviation in view of the large quantities of gasoline that would, no doubt, be consumed by airplanes within the next few years. It is rather to the point that, lately, the Standard Oil Co. also has taken a much greater interest in aviation than it did previously.

One point that could be brought up, especially in a gathering of the Society, is the question of noise. A great many people, sometimes subconsciously, sometimes without admitting it, fear riding in an airplane because of the noise; and I believe also, from my own experience before I learned to fly myself, that much of the airsickness that is experienced by some is brought on by the nerves being affected by the noise. Muffler experts could undoubtedly contribute largely to aviation by developing as efficient a muffler for airplane engines as they have developed for automobiles. The automobile began with the same stigma of being a noisy vehicle, but I believe that the general expansion of use of the automobile is due largely to the fact that its noise has been eliminated.

Mr. Stout said that airplanes that can remain in the air 20 hr. per day are needed. I think it is safe to say that we could build airplanes right now that could be kept in the air 20 hr. per day, if it were not necessary to change the engine, or at any rate, to repair it, in the course of the 20 hr. Mr. Stout's remark was pointed straight at the persons responsible for the development of engines rather than at us unfortunate plane people.

Speaking of the flying qualities of airplanes, I was surprised to hear Mr. Redden say that the operation of airplanes is more a matter of training men than of having the right kind of airplanes. I believe that this has not been proved at all. Last summer, when I was in Europe, I discussed that subject with many people, including the operators of some of the most prominent airlines. I found a very distinct liking for certain types of airplane, based on the results of experience. The actual operators, the chief pilots and the managers of the lines, from their experience with airplanes and what they had seen of those used by others, definitely prefer to use certain types that were used in certain other countries, but they were prevented from doing so by the subsidies, because subsidies are very nationalistic in character and no country will pay a subsidy to a company that gets its airplanes in another country. That, of course, is a thing we do not have to contend with over here. It is one of the little things that make life in Europe interesting, if not more pleasant, especially at the present time. I think Mr. Redden probably could think of a number of types of machine that he might have used, which would have flown, but could not have been kept out in the weather for 3 years and come through in the way his flying-boats have.

A thing that is not realized by everyone is that at this time nothing but fog will keep an airplane from completing its flight on schedule time. Mr. Klemin has mentioned that European conditions cannot altogether be taken into account here, because the climatic conditions are so much better there. He spoke of the London-Amsterdam route as a peculiarly good one, or a very favorable one for flying. I have flown over that line about 10 times and I should like to tell Mr. Klemin that he is somewhat mistaken, because that is the line on which fog is the most prevalent along the North Sea. Up to September, 1922, the line had been operating for two periods of 7 months each, from April to November. During that time, in the second year, they flew an average of about 1000 miles per day, and there were only two cases of forced landing because of engine trouble. One thousand miles per day meant two round-trips between Amsterdam and London; the first year they made one round-trip a day, or about 550 miles. But they had considerable difficulty on account of the fog. Radio, however, has decreased that very much; also, a system of ground signals on both sides of the Channel.

QUESTION:—In view of present conditions and development, which, in your opinion, will find more useful application, the single-engine four or five-seater, or the multi-engine 12 to 18-seater?

PROF. E. P. WARNER:—That depends very much on the type of service. At the present time, for passenger service at least, I should consider that only the multi-engine machine is suitable for use over bad country or at night; but, over routes where the traffic is still necessarily small, it will undoubtedly be more economical to use machines of moderate size equipped with a single engine and to run more machines. In that way, the public can be served better by reducing the time interval between departures.

QUESTION:—Are navigational methods and equipment in their present state of development adequate to the needs of continuous service?

PROFESSOR WARNER:—Mr. Noorduyn largely answered that question. The present navigation methods are ample for all except the most unusually severe conditions, particularly fog. As yet no way of navigating through fog has been found except by the use of directional radio or by one of the leader cable systems, both of which seem to offer some possibilities, the former for long-range work and the latter for leading straight into a landing-field.

QUESTION:—Why not stop all propaganda and talk on the commercial possibilities of aircraft? Is not actual performance the best way to "sell" aeronautics to the people? For this a real passenger-ship design and the actual performance of a model line would be necessary.

PROFESSOR WARNER:—I agree with that statement for the most part except that I do not think it would be wise to stop the dissemination of information as to the facts of present operation. I do not consider that to be propaganda in the more objectionable sense of the phrase. I do think that it is exceedingly desirable that much of the silly talk that has gone on from time to time be abolished. The desirability of showing actual performance is unquestioned, but no single company at the present time is strong enough or wealthy enough to show actual performance on as large a scale as we might

possibly desire; and those parts of the Country that have not yet been reached by the Aeromarine Airways or some similar enterprise will have to depend largely on pictures and on verbal discussion.

QUESTION:—What about the use of parachutes as a safety measure?

PROFESSOR WARNER:—I assume that this question refers to commercial airplanes. The use of parachutes, of course, has proved invaluable for military purposes. Several pilots of the Air Service have been saved after their airplanes had collapsed in flight during a violent maneuver, or when they seemed in immediate danger of collapse. However, I have never quite been able to form a mental image of the passengers in a 12-passenger airplane going through a door, one at a time, the door being about 18 in. wide, and stepping calmly into open space in the expectation that the parachute will open after they have fallen 200 or 300 ft. I believe that all would not get out before the airplane hit the ground, unless they were pushed off.

QUESTION:—In publicity work, why do we not stress the fact that in airplane operation speed and altitude are safety factors?

PROFESSOR WARNER:—That has been stressed; in fact, I think it has sometimes been over-stressed, because speed in itself is not necessarily a safety factor except insofar as each airplane has a minimum speed below which it cannot fly? The higher the minimum speed is, and generally speaking raising the minimum also raises the maximum, the less will be the safety, other things being equal, because the greater will be the danger of damage in a forced landing. However, it is possible to secure a reasonably high maximum speed and still keep the minimum safely low.

I should like to allude to some points in the discussion. Mr. Klemin spoke of geographical considerations in the choice of routes. It is perfectly evident that some routes are much better fitted for aerial exploiting than others. The question of freight versus passengers is a very important one, and was alluded to by both Mr. Klemin and Mr. Stout. Unquestionably, it would be easier to get freight business, up to a certain point, than passenger business. My reason for talking always about passenger business and for being so anxious to see passenger business secured and passenger lines started is that a man may send his express packages by air for 50 years and it will not make any real impression on him. He has been sending mail by air for 5 years and in most cases he does not even know that an air-mail is running, to say nothing of knowing that his own mail is traveling that way when it goes along the air-mail route. But if he travels in an airplane once, he does not forget it. As Mr. Loening has said, if you can get a few of these persons to travel in airplanes, they will talk to their friends, and every one of them will become a center for the dissemination of information.

Mr. Upson's motorbus story is along the line that I am most anxious to bring out. The only trouble about waiting for the public to overcome its inertia is that we may all go broke while we are waiting. I think that without question some improvement has been made at the present time, that the development will proceed, that the trend will be toward a constantly increasing use, and the public will regard the airplane with greater favor, as it has the motorbus.

I was much interested in Mr. Redden's statement that if the price were cut to one-half or one-third the present figure, the number of passengers would not be much increased, because that verifies my own belief that cost is not a serious factor, but that the thing we have to contend with is public fear of the airplane.

I did not speak of privately owned aircraft, as Mr. Loening suggested that I should, because I did not consider them to be a part of commercial aviation. They undoubtedly are an important factor in the construction of airplanes, but my definition of commercial aviation, as I have used it here, is operation for hire.

I should like to speak for a moment on the matter of subsidies, on which both Mr. Loening and Mr. Noorduyn took rather violent exception to what I had to say. Mr. Noorduyn, I think, was hoisted by his own petard because, immediately after having enlarged on the value of some of the European subsidies, he pointed out that some of them are so nationalistic that they are preventing the companies from using the best airplanes. I do not say that no subsidy is good. Subsidies unquestionably have led to the development of commercial aviation in Europe. I said that a great many of the commercial subsidies there are worse than none and I think, on the whole, that it is undesirable to have any subsidy and any direct governmental control over finance, if it can be avoided.

As an illustration of the fact that some of the subsidies are worse than none, I have in mind two airlines, both of which were covering about the same mileage last year, running under the flags of different countries and under different subsidy laws. One of the airlines had two airplanes in service continuously; the other had 97. They were doing about the same amount of work. Some of the subsidies, as I said, put a very high premium on keeping a great number of machines idle or using them for only a few hours a month.

There is no question that the noise of the airplane is important, but I do not rate that importance just as Mr. Noorduyn does. I do not think that noise contributes much to the passenger's fear, although it contributes to his discomfort and often makes him hesitate to ride again. I have had occasion to talk to many passengers and have found that noise makes them happy rather than otherwise, if they have fear because, when they get into the airplane, they are thoroughly imbued with the idea that their continued existence is dependent upon the continued functioning of the engines, and the more noise the engines make the more evident it is that they are functioning. That is not purely a joke. I have heard competent engineers argue for the use of twin-engine airplanes solely because the engines are out where the passengers can see that they are still running, although the two-engine machines are admittedly more subject to forced landing than are those with a single engine.

California Air-Cleaner Tests, 1924 Series

By A. H. Hoffman[1]

Semi-Annual Meeting Paper *Illustrated with* Photographs

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REFERENCES are made to published results of similar tests of air-cleaner devices conducted in 1922, and the scope of the 1924 tests is described. Road tests of air-cleaners were carried out and the tabulated data are presented. Efforts were made to find out how much dust the engine would draw in if the cleaner and connections were removed, and to catch and to weigh the dust the air-cleaner being tested failed to catch.

Dust was raised by a car running about 50 ft. ahead of the test-car and, to produce heavy dust-conditions, it dragged the road with a chain attached to form a loop behind it. The leading drivers maintained as nearly as possible a constant speed of 25 m.p.h. and chose the dustiest part of the road, following the same course in all the rounds.

The specific items of the 1924 programs were (*a*) to continue the testing work begun in 1922, (*b*) to devise a satisfactory method of test for types of air-cleaner that cannot well be tested by the 1922 method, (*c*) to determine how much dust an automobile or truck encounters in service and (*d*) to find out how the use of air-cleaners affects the rate of engine wear.

After describing the "absolute" air-cleaner used in connection with the air-cleaners being tested, standard dust for testing purposes and Fuller's earth are discussed, inclusive of some tests made of the latter substance. Road tests are treated generally and specifically, road-test and laboratory-test comparisons are made and the 32 air-cleaners submitted for test are described, together with tabular data of the results obtained while testing them.

AIR-CLEANERS have different degrees of efficiency. Certain places exist in the United States and elsewhere where it is worth having an air-cleaner of any sort on an automotive machine, if the cleaner has any efficiency whatsoever. On a typical desert road in California, the dust and sand encountered constitute a very different proposition from that found on the highways. In New Mexico, Southern California, Texas and Arizona, I have known of cases in which sandstorms have cut the enamel entirely off of one side of a car, clear down to the bright steel. In such cases it is not necessary even to have an efficient air-cleaner to do a great amount of good. About 5 years ago I saw an air-cleaner on a tractor in Northern California which was nothing more than a periscope. Its efficiency as an air-cleaner was about 97 per cent. The engineer of a large fig-growing holding near Fresno, Cal., told me that tests he had made showed a periscope 2 ft. high to be the equivalent of taking out 90 per cent of the dust that was encountered by the engine.

I am not predicting at all that automobiles will be equipped with periscopes that will extend up into the air above them, but perhaps such a use on trucks is possible. A periscope might be developed which would go up to the inside of the cage or front part of the machine and yet not be unsightly; but, for automobiles, I think that would be practically out of the question. However, I want to make a plea for the ordinary user of automobiles. Not 1 per cent of the cars in use give evidence that the designer has devoted any thought whatever to the possibility that an air-cleaner might be wanted on the engines of the car. The same statement is true for trucks. It costs about $5 just to make it possible to put an air-cleaner on some machines.

The laboratory tests here reported follow closely those of the 1922 series. The 1922 results are stated briefly in the University of California Agricultural Experiment Station Bulletin No. 362, entitled Dust and the Tractor Engine. Also, they are given in detail in *Agricultural Engineering*, June and July, 1923.

The road tests were made because the regular laboratory test was inapplicable to some cleaners that were sent in for test. Considerable study was given the subject so that the road tests as run might be duplicated readily elsewhere. Two main things are sought: First, to find out how much dust the engine will draw in if cleaner and stove and their connections are removed; second, to catch and to weigh what the tested cleaner fails to catch. To determine the dust encountered, a 90-deg. ell of plumbers' thin brass tubing having an outside diameter of 2 in. is placed with its opening forward on the level with the midline of the radiator core end, longitudinally and latterly, as nearly as possible to the regular position of the carbureter inlet on the car or the truck on which the test is made. The hood is closed, holes being cut for connections to the "absolute" cleaner. The absolute cleaner is a slight modification of No. 17 of the 1922-test series. The run with the cleaner off is made as nearly as possible like the run with the cleaner on.

Dust is raised by a leading car 50 ft. ahead. For heavy dust-conditions, a standard chain is dragged in a loop. For medium dust, no drag is used. The dust per mile caught in the absolute air-cleaner is made the basis of the efficiency determinations. Check-runs are necessary. The leading driver endeavors to maintain a constant speed of 25 m.p.h., to pick the dustiest part of the road and to follow the same course as nearly as possible in all the rounds. The data are interpreted in accordance with what is deemed to give results nearest to the truth, when the circumstances of the tests are known, and reference is made to the notes in connection with the road-test tables.

Too much stress should not be placed on the results of these first road-tests. They should first be verified by several repetitions. The position of the air-cleaner on the car, the tightness of the fan-belt, the diameter and the design of the fan, the car speed, type of soil, conditions of road, wind, weather and the like may change the results very appreciably. In the road test of June 2, the fan-belt was found slipping considerably at the close of the tests. Also, on that day Cleaner No. 56 was found shifted slightly from its correct position.

[1] Agricultural engineering division, University of California, Davis, Cal.

Scope of the Present Work

The present air-cleaner program at the University of California Agricultural Experiment Station includes the following four items:

(1) Continuing the testing work. The first series of tests, references to which have been made previously, was completed in 1922
(2) Devising a satisfactory method of test for types of cleaner that cannot well be tested by the 1922 method
(3) Determining how much dust an automobile or truck encounters in service
(4) Finding out how the use of air-cleaners affects the rate of engine wear

Since the present work is built largely upon that of the 1922-test series, it may be well to review briefly the method then devised. That method was (*a*) to send into the cleaner under test, at a measured rate, air containing a definite quantity of a standard dust finely divided and fed into the ingoing airstream at a regular rate; (*b*) to catch in a so-called absolute cleaner the dust not stopped by the tested cleaner, and (*c*) simultaneously to take manometer readings of the choking effect produced by the tested cleaner. The efficiency of dust separation was obtained by weighing the dust caught in the absolute cleaner, determining its proportion of the standard amount fed in and subtracting this percentage from 100. Regarding the regular rate mentioned in item (*a*) just stated, this is about 30 min. for a 50-gram sample.

The "Absolute" Air-Cleaner

The so-called "absolute" air-cleaner consists of wooden frames tightly made, so that they are free from air-leak to a large extent. They are 18 in. in the clear. We use anywhere from two to six of them in series. We started in with six to determine how much of the dust was being permitted to escape; in other words, to see how efficient our absolute air-cleaner is. We found that by plotting a curve between the amounts of dust caught on the several cloths of the cleaner and the number of cloths, we were able to determine what amount would have been caught, or the additional amount that would have been caught, if we had had an indefinite number of cloths. From the curve so obtained, we could make our correction, having two or three, or whatever the number may be of cloths in the absolute cleaner. So, while it is not an absolutely perfect cleaner, we can make it absolute, so-called, by the use of this curve for correcting. The tested cleaner is then placed in position and has air drawn through it by a four-cylinder tractor-engine. It is connected to a venturi air-meter.

The 50-gram standard sample of dust is put into a metal tube equipped with a plunger. The plunger is moved slowly to push the dust column against a revolving bristle brush. The air enters the housing of this bristle brush, an inner housing also being provided to prevent any centrifugal blower action of the wheel itself. I wished to prevent blow-back, and I found this arrangement fairly satisfactory. The General Motors Research Corporation has duplicated this device, I understand, and is getting very good results by using the blast of the brush instead of discarding it as I had to do, but they have very much better equipment. Their tube is of cast aluminum, very finely machined. I had to use a tin tube.

The air-screen takes this finely divided dust; the dust that does not enter in "gobs." I found a marked difference in apparent efficiency between feeding dust not finely divided and dust that is brushed out very fine. The dust goes on into the tested air-cleaner, then into the absolute air-cleaner and on into the engine. We get the manometer reading across the tested air-cleaner and also at the intake of the tested cleaner, using simply an added connection for one side of the inlet. A complete illustrated description appears in the 1922 report.

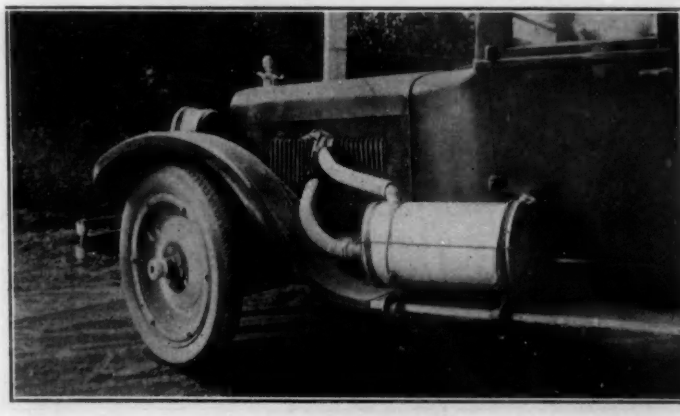

Fig. 1—How the Absolute Cleaner Is Mounted on the Test Car
This Cleaner Is Inserted between the Cleaner That Is Being Tested and the Carbureter and Shows How Much Dust Passes through the Cleaner Undergoing a Test

The Standard Dust

Every air-cleaner built can be made to test 100 per cent efficient if one only chooses shrewdly the "dust" to be fed into it. The particles must be large enough so that they cannot pass the labyrinths of a filter and must be heavy enough so that inertia or gravity will be sure to leave them behind when the air going toward the carbureter swings around the turn. I have been asked often to recommend "some common material that is cheap and easily obtained" to be used as a substitute for standard air-floated dust. If only a single mechanical principle were involved in air-cleaner design, it might be possible to find a satisfactory substitute. If the air-cleaner maker desires to test his product to determine the best design, the use of a substitute may easily lead to an erroneous decision, since it may not be known whether the feature that gave best results on the substitute would give the same, better or worse results on real dust. The car or truck builder trying to decide wisely which of several makes of cleaner to buy has no assurance whatever that the cleaner that came out best when tested with cement will give superior performance on the road.

Fuller's Earth

Fuller's earth has been much used for testing air-cleaners. To get some idea as to its probable value for this purpose, I secured a few samples from different sources and made tests. The work is not yet completed but the results obtained are stated in Table 1 and give some idea as to the desirability of using this material for test purposes.

A test that we use for dryness of the dust is to put into each one of two bottles a 50-gram standard sample. One bottle is sealed in with alcohol shellac; the other has

Table 1—Tests of Fuller's Earth

	No. 1 Standard Dust	Fuller's Earth Samples No. 1	No. 2	No. 3
Moisture, per cent	0.00	2.24	10.34	8.70
Proportion Passing through a Screen of 200 Meshes per In., per cent	98.60	98.56	68.02	53.20
Specific Gravity when Well Shaken Down	0.68	0.83	0.70	0.68
Make	...	U. D. Co.	B. K. H. Co.	J. C. Co.

FIG. 2—HEAVY DUST CONDITIONS SET UP DURING THE TEST
In Making the Test a Car Is Run Approximately 50 Ft. ahead of the Test Car at a Constant Speed of 25 M. P. H. The Driver of the Test Car Endeavors To Maintain the 50-Ft. Interval and Keep the Radiator of His Car in the Densest Part of the Dust Cloud

a glass stopper. When the dust is not satisfactorily dry, if the bottle is turned its interior wall above the bulk of the sample remains clear. If, however, the dust is satisfactorily dry, the upper interior wall of the bottle is soiled by the dust; when the bottle is turned, the dust films the glass inside.

The salient points in Table 1 are as follows. I obtained three different samples, two of which were from the stocks used by commercial companies for testing air-cleaners. The third sample was from a drug-store. The respective moisture-content is shown for each sample. By way of contrast, in a recent road-test made in California, we found a little more than 3 per cent of moisture in the dust caught in a Bennett air-cleaner. In this Fuller's earth, Sample No. 2, we found more than 10 per cent of moisture. A 200 mesh per in. screen was used to determine the fineness of the three samples. Our No. 1 standard dust is 98.6 per cent for passing through the 200 mesh per in. screen, and the drug-store sample of Fuller's earth is almost exactly the same. The percentages for the other samples are shown in Table 1 also, as well as the specific gravity. The people who sell Fuller's earth say they have no specification as to its fineness or as to its characteristics; so, one may get all sorts of stuff when buying Fulller's earth.

FIG. 3—CHAIN DRAG USED TO PRODUCE HEAVY DUST CONDITIONS
A Chain 25 Ft. Long of 13/32-In. Stock with 1⅜ x 2⅛-In. Links and Weighing 39.3 Lb. Was Dragged behind the Leading Car. The Ends of the Chain Were Fastened to a Wooden Bar 74 In. Long and 30 In. from the Ground, Thus Forming a Loop

Three efficiency tests of Fuller's earth were made on a Bennett dry centrifugal air-cleaner, No. 23 of the 1922-test series. The apparent efficiencies were, for Sample No. 1, moist, 68.5 per cent; for Sample No. 2, moist, 77.9 per cent; and for Sample No. 2, dry, 81.0 per cent. The average of six tests on the same air-cleaner in 1922, using No. 1 Standard Dust, indicated an apparent efficiency of 42.7 per cent.

It is highly probable that, when using Fuller's earth, the deviation from results obtained in standard tests would be very different for air-cleaners of other types. It seems utterly hopeless to try to calibrate or standardize any dust substitute, whether it be Fuller's earth, cement, alundum or flour, so that it can be used with any degree of assurance that all the calculations may not be upset by the advent of a cleaner of new design. Furthermore, every new lot of such a dust substitute would require a new calibration or at least a determination of its physical characteristics to assure having it approximately the same as a previous lot.

The use of a dust substitute is not only undesirable, but unnecessary. If it is not feasible to build an air-floating device recourse may be had to several machines now on the market that are designed for the commercial production of fine powders. If a dust comparable in physical characteristics with those of our No. 1 Standard Dust is made up by mixing air-floating portions of several representative soils obtained from the region in question, I will guarantee the results obtained to be more reliable than those that can be had by using any substitute. The standard dust, bone-dry and hot, is weighed out into 50-gram samples and bottled securely. The bottles are stored in a dessicator. If appreciable moisture is absorbed due to air-leaks, the dust, when tumbled about in the bottle, will leave the inner surface of the glass practically clean. If dry, the surfaces will be noticeably clouded.

ROAD TESTS

The objections against field tests of air-cleaners on tractors, mentioned in the 1922 report, hold against road tests of automobile-type air-cleaners, since the same set of uncontrollable variables is operative. A laboratory test under controlled conditions is much more desirable, provided it is possible. It is a very simple matter with most air-cleaners to adapt the tested air-cleaner so that it can be connected in the line between the dust-feeding device and the absolute air-cleaner. With some air-cleaners that depend upon the radiator fan for their action, this is almost, if not wholly, impossible. Various modifications of the standard laboratory method have been proposed and some have been tried out, with indifferent success. It is hoped ultimately to find a satisfactory laboratory test. For the present, however, it seems that a road test, notwithstanding its difficulties and variables, is the best that is available.

A road test must determine two things: how much dust the carbureter would take in if there were no air-cleaner, and how much dust the tested air-cleaner either catches or fails to catch. The air-cleaner under test is placed in its normal or approved position on an automobile or on a truck. An eiderdown absolute air-cleaner is inserted between the tested air-cleaner and the carbureter, as shown in Fig. 1. All joints are made air-tight and mechanically secure. The hood is closed, because it acts as an air-tunnel; this is important for some types of air-cleaner of this kind. Connections to the absolute air-cleaner are designed to cause the least obstruction to the passage of air from the fan. A piezo-

meter ring of proper construction is placed at the air-cleaner outlet and connected to a U-tube manometer on the instrument-board. Readings of the amount of vacuum are taken when the speedometer shows that normal speed is maintained.

Dusty conditions are produced by running another car about 50 ft. ahead of the test car as shown in Fig. 2. The forward driver endeavors to maintain a constant speed of 25 m.p.h. and to run in the same part of the road during each circuit of the course. The following driver endeavors to maintain the 50-ft. interval and to keep the radiator of his car in the densest part of the dust cloud. In comparative tests, the leading car should be of the same make and model, and the drag, if one be used, should be of the same kind and similarly placed.

In the first tests described here, a 1922 Ford roadster was used to produce the dust cloud. In runs Nos. 8 and 9, it was used without a drag. In runs Nos. 1 to 7 inclusive, a chain 25 ft. long, weighing 39.3 lb., of 13/32-in. stock and having links 1⅜ x 2⅛ in., was dragged behind the Ford roadster. The ends were 30 in. above the ground and 74 in. apart; they were tied to the ends of a wooden bar. Thus, the chain formed a loop, as shown in Fig. 3.

The course for runs Nos. 1 to 9 inclusive was 3.26 miles per circuit; about one-half lies in a north and south direction and the other one-half in an east and west direction. Large trees, mostly black-walnut trees, flank one side of the road the entire distance. Most of the east and west portion has trees on both sides. This markedly reduced the effects of the wind. The road is on soil that is principally Yolo fine sandy loam. The middle of the road has been gravelled but on each side is an ungravelled portion that is much used by wagon traffic and has dust 2 or 3 in. deep in many places. These side portions of the road were used whenever possible, except for run No. 1 (which was discarded) in which the middle of the road was followed for a total of about one-fourth of the mileage.

To determine the dust contended with, "blank" runs were made. In these the absolute air-cleaner was used alone, placed as in the other tests but with its intake connected to a 90 deg. ell of plumbers' thin brass tubing having an outside diameter of 2 in., as shown in Fig. 4. The open end of the ell is forward and is placed, vertically, midway between the top and the bottom of the radiator core and, longitudinally and laterally, as close as possible to where the carbureter would get its air if the air-cleaner and the stove and their connections were removed. The hood is closed as in the runs made with the tested air-cleaners.

I hope that we can standardize somewhat on a placing for air-cleaners so as to be enabled to repeat air-cleaner experiments on different machines and get something like comparable results. If we put the intake of the ell down where the carbureter intake is, I am sure that, in many cases, where obstructions are ahead of that point, such as the generator, the engine or various accessories that might be found under the hood of an automobile, we will have eddies and screening effects that will not occur if we have the intake pipe higher up. So, I specify, vertically, midway between the top and the bottom of the radiator core and, laterally and longitudinally, as close to the carbureter intake as is possible, if all the connections of the stove, the air-cleaner and the like of the carbureter are removed. We follow that as a kind of standard test, and use the 2-in. thin brass-tubing ell for the end of the device.

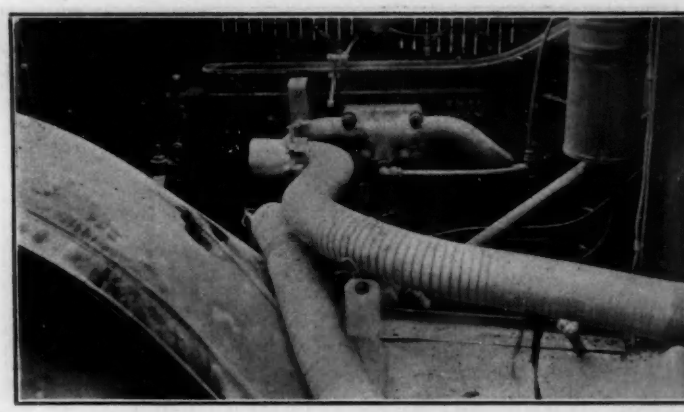

FIG. 4—CONNECTIONS FOR THE ABSOLUTE CLEANER IN THE "BLANK" RUNS

In These Runs Which Were Made To Determine the Dust Contended With, the Absolute Cleaner Only Was Used. The Intake of the Cleaner in This Case Was Connected to an Ell of 2-In. Thin Brass Tubing, the Open End Being Forward and as Nearly as Possible in the Position Where the Carbureter Would Get Its Supply of Air if the Air-Cleaner and Stove and Their Connections Were Removed

SPECIFIC ROAD-TESTS

Table 2 shows the results of road-test runs Nos. 1 to 5, made June 2, 1924, and Nos. 6 to 9, made June 3. The test car was a Rickenbacker Model-24 Sedan and the leading car was a 1922 Ford Model-T roadster. A description of the course, the placing of the air-cleaners, the fan-belt conditions and the like is included in the paper. The apparent efficiencies found in these road tests are not regarded as equivalent to the results of our standard laboratory tests. The course is southwest of Davis, Cal.

Referring to Table 2, the dust encountered per mile in run No. 5 was used as a basis for determining the efficiency of air-cleaners Nos. 48A and 56, tested June 2, 1924; that in run No. 6, for the air-cleaner and the conditions of run No. 7; that in run No. 9, for air-cleaner and the conditions of run No. 8. For cleaner No. 23, the

TABLE 2—ROAD TEST OF AIR-CLEANERS

Run	Cleaner	Miles	Elapsed Time, Min.	Average Speed, M.P.H.	Vacuum at 25 M.P.H., In. of Water	Dust in Absolute Cleaner, Grams	Dust Per Mile, Grams[a]	Efficiency, Per Cent	Conditions: Dust	Conditions: Temperature, Deg. Fahr.	Conditions: Humidity
1	Absolute Only	16.40	42.5	23.1	......	31.35	1.91	...	Med. Hvy.	87.0	48.0
2	No. 23 of 1922	32.60	86.0	22.8	3 to 5	34.12	1.55	32.3	Heavy	95.0	37.0
3	I. & M. Perfection	32.60	81.0	24.1	3 to 5	40.35	2.41	49.6	Heavy	95.0	36.0
4	Cyclone Automatic	13.00	33.0	26.0	3 to 5	7.52	2.41	76.0	Heavy	87.0	43.0
5	Absolute Only	9.70	26.5	22.0	......	23.42	2.41	...	Heavy	83.0	48.5
6	Absolute Only	9.75	25.5	22.9	......	22.27	2.28	...	Heavy	95.5	28.0
7	I. & M. Perfection	9.80	24.0	24.5	3 to 4	3.40	2.28	84.8	Heavy	93.0	39.0
8	I. & M. Perfection	26.00	64.5	24.2	3 to 4	2.61	0.60	83.2	Medium	82.0	42.0
9	Absolute Only	13.00	26.7	29.2	......	7.77	0.60	...	Medium	77.0	53.0

[a]Used as a basis of percentage.

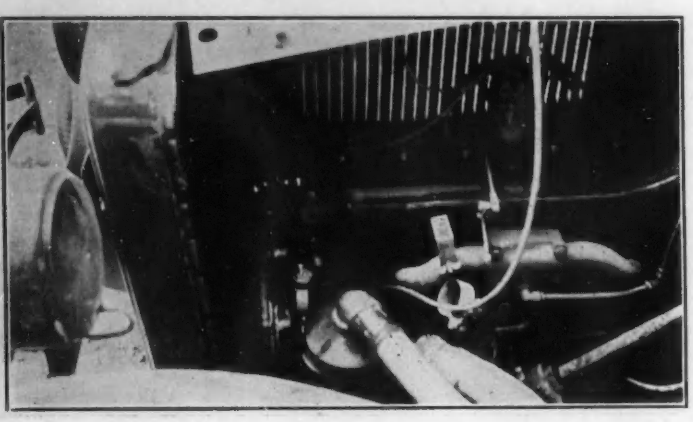

FIG. 5—A CLEANER MOUNTED FOR THE ROAD-TEST
In Mounting This Cleaner in the Car the Intake Was Placed as Nearly as Possible in the Same Position as the Absolute-Cleaner Intake Shown in Fig. 4

dust caught by it and by the absolute air-cleaner in run No. 2 were added to obtain the percentage basis.

ROAD AND LABORATORY-TEST COMPARISONS

An effort was made to establish the relation between the efficiencies obtained in a road test and those obtained under standard conditions in the laboratory. With this in mind, air-cleaner No. 23 of the 1922-test series, a Bennett dry centrifugal, was used in run No. 2. This air-cleaner was chosen because it uses the inertia principle, is compact and had been given several laboratory tests. Its intakes were placed as nearly as possible in the same position as specified for the standard position of the intake of the brass ell used in the "blank" runs, as shown in Fig. 5. The dust in the receptacle of the air-cleaner after run No. 2, the cleaner having been jarred vigorously with a mallet, weighed 16.82 grams, undried, and its moisture content was 3.45 per cent. The dry dust passing the 200 mesh per in. screen amounted to 95.6 per cent. The dust it did not catch evidently was finer than that.

The efficiency of air-cleaner No. 23, as found in the 1922-test series, was 42.7 per cent, this being an average of six tests. The one road-test, run No. 2, Table 2, gave 32.3 per cent, or 57.3 per cent, depending on whether the sum of the dust caught in the tested air-cleaner and in the absolute air-cleaner in run No. 2 or that caught in the absolute air-cleaner in run No. 5 is used as a basis of percentage. While the results given probably have considerable significance, repetition of the road tests under various conditions of weather, temperature, humidity, roads and the like is imperative before anything like exact comparisons will be permissible.

In further explanation, under run No. 2, Table 2, referring to the efficiency column, add to the 32.3 per cent efficiency, 57.3 per cent. The 32.3 per cent is the efficiency when we take the sum of the dust caught in the jar of the Bennett tested air-cleaner and the dust caught in the absolute air-cleaner. We add them to make the 100 per cent, and then divide the amount of dust caught in the Bennett air-cleaner by the sum of the two; the result is 32.3 per cent, this being the efficiency of the cleaner in that case, assuming that all the dust that was lost by the tested air-cleaner was caught in the absolute air-cleaner, which was very nearly true. The 57.3 per cent referred to is the efficiency if we use the next blank-run as the basis of percentage. The indications are that the placing, as before mentioned, of that open brass-tube would tend to whitewash the air-cleaners that are tested by this method. However, by standardizing or by tying to our laboratory tests, I think we can get results that will be worthwhile.

The I. & M. Perfection air-cleaner, No. 56, on the first day of the road tests, was supposed to be in its normal position; but at the close of the tests it was found with its center 3/8 in. out from the correct position. This caused the cleaner's shell-circle to extend 1½ in. beyond the fan-blade-tip circle instead of having a normal extension of about 1 in. Also, at the close of the first day's tests, the round rubberized fabric fan-belt was found considerably worn and rather loose on the pulleys. It is impossible to state the degree to which these two factors influenced the efficiency of air-cleaner No. 56 in the first day's tests. Cleaner No. 48 A had the loose belt to contend with but was in a position approved by the maker. Three things probably combined to produce a higher net efficiency in cleaner No. 56 in the second day's tests: first, and probably of greatest importance, the tighter fan-belt; second, the higher placing, making the total dust actually encountered by the cleaner less; and, third, the placing within the fan-blade-tip circle, which conceivably gave a higher air velocity through the cleaner shell.

It will be observed that with the lighter dust-cloud, when no drag was used on the leading car, the efficiency was somewhat lower than with the heavy dust-cloud. The reason is that the chain raised considerable coarse material; occasionally a pebble would strike the windshield of the test car. This coarser material would be easier for an inertia-type air-cleaner to handle than fine material would be. It should also be noted that, of the dust caught in cleaner No. 23 during its run in heavy dust, 95.6 per cent passed a 200 mesh per in. screen, as stated in Table 2.

On June 11, 1924, another set of road-tests was run, the results being stated in Table 3. The leading car was a Ford Model-T 1922 touring car and the test car a Chevrolet Superior roadster equipped with a Wishon air-cleaner, No. 34. The course was all on earth roads on the University Farm at Davis, Cal., around a rectangular block of fields, 1.27 miles per round. No trees were

TABLE 3—ROAD TEST OF AIR-CLEANERS ON UNIVERSITY FARM, DAVIS, CAL.

								Conditions		
Run	Cleaner	Miles	Average Speed, M.P.H.	Vacuum at 25 M.P.H., In. of Water	Dust in Absolute Cleaner, Grams	Dust Per Mile, Grams[3]	Efficiency, Per Cent	Dust	Temperature, Deg. Fahr.	Humidity
10	Absolute Only	12.7	23.1	......	14.22	1.119	...	Medium	86.5	25.5
11	Absolute Only	8.9	22.7	......	29.25	3.286	...	Heavy	83.5	30.0
12	Wishon	15.3	21.6	1 to 2½	13.76	0.899	72.6	Heavy	80.0	42.5
13	Wishon	15.3	22.1	1 to 2½	5.74	0.375	68.8	Medium	80.0	38.0
14	Bennett No. 23	7.6	21.2	¾ to 1¼	4.03	0.530	55.9	Medium	77.0	40.0
15	Bennett No. 23	7.6	21.7	¾ to 1¼	14.78	1.944	55.7	Heavy	74.5	47.5
16	Absolute Only	7.6	21.2	......	33.31	4.383	...	Heavy	72.5	52.0
17	Absolute Only	8.9	21.8	......	11.42	1.283	...	Medium	69.0	62.0

[3]Caught in absolute air-cleaner.

TABLE 4—AMOUNT OF DUST ENCOUNTERED

Make of Car	Model	Mileage	Dates, 1923-1924 From	To	Use and Road	Kind of Cleaner	Dust Caught by Cleaner, Grams	Dust Per Mile, Grams
Dodge Touring	1923	1,228	Dec. 29	June 7	About One-Half on Paving	Pomona	5.50	0.00450
Ford Truck	1923	386	June 5	June 24	Express, Mostly on Earth Roads	Bennett, Oil-Type	1.03	0.00270
Marmon Sedan	34	1,615	April 9	June 10	Mostly on Paving	Pomona	0.73	0.00045
Truck	Class B	304[a]	April 1	May 31	California Highway Commission Road	"No. 17"	27.15	0.08900

[a] Loaded with 2.5 cu. yd. of earth.

near. Standing grain flanked the road in several places. For the heavy dust, the same drag-chain was used as in the earlier tests. It will be noted that the dust encountered increased during the tests. This was due no doubt to the effect of dragging the chain repeatedly over the same road. In the first road-tests this effect was not noticeable, if present, probably because the dust was deep at the beginning of the tests. The connections and the absolute air-cleaner used were as in the first road-tests.

The apparent efficiencies stated in Table 3 are not regarded as equivalent to the results of our standard laboratory tests. Regarding the basis on which the efficiencies were calculated, that for run No. 12 was the dust per mile obtained in run No. 11; for runs Nos. 13 and 14, the average of the dust obtained in runs Nos. 10 and 17; and for run No. 15, the dust obtained in run No. 16. The course, the placing of the cleaners, the fan-belt conditions and the like have already been described.

These road tests are not to be considered as in any sense the equivalent of our regular laboratory tests. They have been rather carefully conducted, but are subject necessarily to considerable probable error.

Amount of Dust per Mile

It is evident that the air-cleaner in automobile service generally has an easier time of it than the one in truck or tractor service. Data are being collected to find out how much dust is encountered in a given use. Highly efficient dust-collectors have been installed on a number of automobiles and trucks, but it is yet too early for a conclusive report. Table 4 presents data on the amount of dust encountered.

Reduction of Engine Wear

What effect the air-cleaner will have on engine wear is being studied by a number of large commercial companies that use fleets of trucks or automobiles. Only a very limited amount of information is available. One engineer reports from Los Angeles, Cal., that two Buick six-cylinder touring cars ran almost exactly 27,000 miles, each in the same service. One was run without an air-cleaner; the other was equipped with an air-cleaner of high efficiency. The average cylinder-wear for the first car was 0.008 in. and for the second car 0.001 in. The first car required new pistons and rings and several new valves; the second car required no replacements.

Cooperative Experimental Work

A considerable amount of good information is expected to result from a cooperative experiment now being carried on by the California Highway Commission and the Agricultural Engineering Division of the University of California. Eight Class-B trucks in a large fleet of different makes used on a mountain-road construction-job were chosen for a comparative test of air-cleaners. All the eight trucks were practically new, but they were torn down and the engine parts most subject to wear measured; the small parts were weighed on chemist's balances. Six of these trucks are equipped with one of the following air-cleaners: Pomona, Protectomotor, Stromberg, United (ejector), Wishon and the eiderdown cleaner of the 1922 tests. Two trucks are unequipped. Errors due to dust entering by way of the breather are obviated, since the breather-cap is a check-valve opening outward only. The placing of the several air-cleaners was made as nearly the same as was feasible. Samples of the oil drained from the crankcase at each week-end are sent in for analysis. Records are kept of mileage, fuel and oil consumption and the like. Vacuum readings are taken at intervals with the engine idling against a governor set for a road speed of 15 m.p.h. The average dust encountered is determined by the eiderdown cleaner and checked by the Pomona.

As shown in Table 5, a total of 32 air-cleaners, 20 different kinds, from 17 manufacturers or inventors, are entered in the 1924 test series. A total of 15 of these air-cleaners are designed principally for automo-

TABLE 5—AIR-CLEANERS OF THE 1924 SERIES

Total Number	32
Designed for Tractor Use, Nos. 32, 33, 44, 52, 55 and 57	6
Designed for Automobile or Truck Use, Nos. 31, 35, 35A, 35B, 36, 37, 38, 39, 40, 41, 42, 43, 46, 50 and 51	15
Usable for Automobile or Tractor, Nos. 34, 45, 47, 48, 48A, 49, 49A, 53, 54, 56 and 58	11
Water Type, Nos. 32 and 33	2
Dry Type, Total of 16	
Felt Filter, Nos. 35, 35A and 35B	3
Rubber-Sponge Filter, Nos. 41, 42 and 43	3
Inertia Principle, Nos. 31, 34, 47, 48, 48A, 49, 49A and 56	8
Filter and Inertia Principle, No. 50	1
Inertia and Gravity Principle, No. 54	1
Using Radiator Fan, Nos. 34, 47, 48, 48A and 56	5
Oil Type, Total of 14	
Plain Fiber Filter, Nos. 39, 40, 52, 55 and 57	5
Expanded Metal Filter, No. 51	1
Dry Centrifugal and Fiber Filter, Nos. 36, 37 and 38	3
Oil Centrifugal and Wire Filter, Nos. 52 and 58	2
Oil Centrifugal and Fiber Filter, Nos. 44, 45 and 46	3

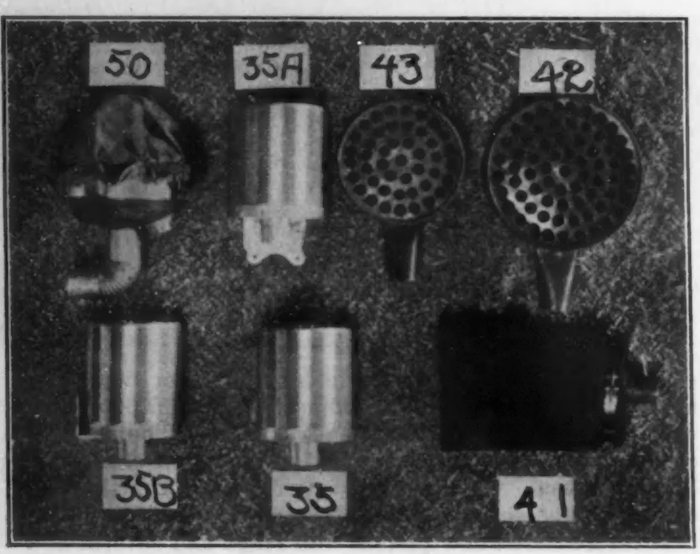

FIG. 6—SOME OF THE DRY-TYPE CLEANERS

Six of the Seven Illustrated Use Filters, the Exception Being the Donaldson, No. 50, Which Is Said To Combine the Filter and the Inertia Effect. The Three Protectomotor Cleaners, No. 35, 35*A* and 35*B*, Have Filters of Felt Placed over Fluted Cylinders of Wire Mesh, Thus Giving a Larger Area in a Small Compass. In the Hose Cleaner, No. 41, Sponge Rubber in the Form of a Flat or Partly Oval Bag Drawn over a Wire Frame and Clamped Securely around the Metal Base of the Frame Is the Filter Medium. In the Gordon Cleaners, Nos. 42 and 43, the Rubber Is Cut into Circular Discs 1 In. Thick and Held between Punched Metal Plates in a Sheet-Steel Shell

bile use; 11 others are usable for either automobile or tractor; and 6 are primarily for tractor use. These last mentioned, together with some late arrivals, are not yet all tested. The lists will remain open until the early fall of 1924.

DESCRIPTION OF CLEANERS

Only two entrants represent the water type of cleaner: the J. I. Case Threshing Machine Co., air-washer No. 33, and a Tractor Appliance Co., Siphon, No. 32. These differ only slightly from the ones of the same makes in

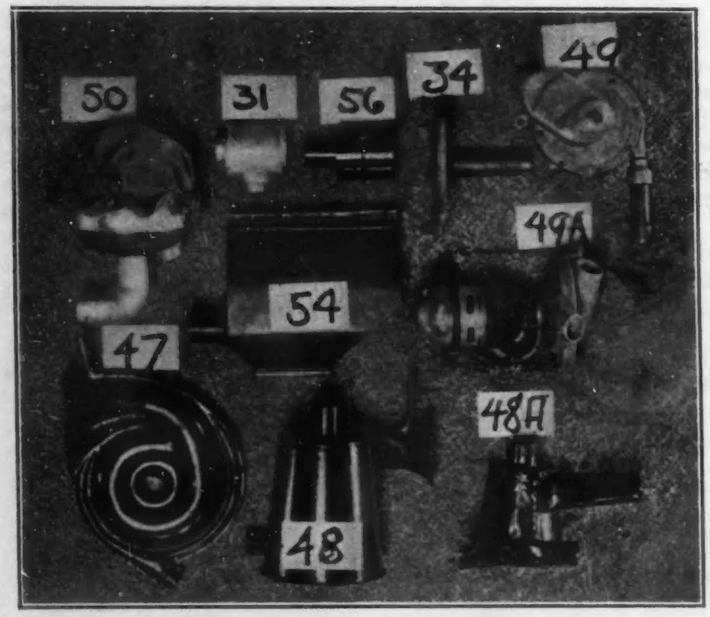

FIG. 7—MORE OF THE DRY-TYPE CLEANERS

These Cleaners Are of the Inertia Type. The Twister, No. 31, Depends for Its Action upon the Whirl Given the Air by a Set of Spirally Placed Vanes; the Wishon, No. 34, the Turbo Automatic, No. 47, the Cyclone, Nos. 48 and 48*A*, and the I. & M. Perfection, No. 56, Depend at Least in Part on Blast of the Radiator Fan for Their Action; the Palmer, No. 54, Relies upon Inertia and Gravity To Separate the Dust; and the Thompson, Nos. 49 and 49*A*, Is in Effect a Centrifugal Air-Pump

the 1922 tests. The dry type is represented by 16 entrants. Of these, six have filters as shown in Fig. 6, and nine make use of the inertia effect as shown in Fig. 7; one, No. 50, is said to combine both these features. Three, Protectomotor Model C-4, Nos. 35, 35A and 35B, have filters of felt placed over fluted cylinders of wire screen, thus providing a large area within a small compass. Two of these are nearly exact duplicates; the third, No. 35B, differs from the others in having no staples in the bottoms of the flutes. One, Hose, No. 41, and two, Gordon, Nos. 42 and 43, a total of three, use sponge rubber as the filter medium. In the Hose, No. 41, the sponge is in the form of a flat or partly oval bag drawn over a wire frame and clamped securely around the metal base of the frame. In the Gordon, Nos. 42 and 43, the rubber is cut to circular discs about 1 in. thick and held between punched metal plates in the sheet-steel shell. No. 50 is said to combine the centrifugal with the filter principle. Its exact nature has not been disclosed. A canton-flannel bonnet is drawn down over the wire support surrounding the air inlet and strapped around the middle of the cleaner shell.

All the nine dry inertia-type cleaners shown in Fig. 7 are new to me. The Twister, No. 31, depends for its action on the whirl given the air by a set of spirally placed vanes. The Wishon, No. 34; the Turbo Automatic, No. 47; the Cyclone Automatic, Nos. 48 and 48A; and the I. & M. Perfection, No. 56, depend at least in part on the blast of the radiator fan for their action. The Wishon has simply a set of narrow louvers in the face of a flat cell placed between the radiator and the fan. The fan blades cutting past the louvers remove the dust from the entering air. The Turbo Automatic, No. 47, approaches an involute in shape. It consists of two halves of pressed steel. A narrow slit between the shell proper and the surrounding tubular portion allows the escape and ejection of the separated dust. The small tubes shown projecting from cleaners Nos. 47 and 48 in Fig. 7 are not regular parts of these cleaners, but were used to feed-in the standard dust.

The Cyclone Automatic cleaners, Nos. 48 and 48A, are of the centrifugal type and depend for the whirling action on tangentially placed inlets. A tangentially placed dust-outlet at the base ejects the separated dust. No. 48A differs from No. 48 in size and in having a venturi tube below to enable the fan blast to assist in the ejection. The I. & M. Perfection, No. 56, consists of a conical cap over the end of the air-intake tube and a large tubular shell surrounding it. Air from the radiator fan rushing through between the shell and the cone must whip around the rear edges of the cone to enter the tube leading to the carbureter. The dust, failing to make the sharp turn, is carried on back and out by the inertia effect. The Palmer, No. 54, depends on inertia and gravity to separate the dust. It consists of a shell containing baffle-plates. The Thompson, Nos. 49 and 49A, is, in effect, a centrifugal air-pump.

Dusty air enters the housing near the shaft on one side of the runner or impeller and is thrown to the periphery of the housing at one point in which an outlet is provided for the dust thrown out by the centrifugal action of the impeller. The cleansed air passes along the impeller and against its pumping action to the outlet, which is near the shaft on the side opposite to the intake. Curved vanes near the outlet are designed to guide the whirling air to the outlet and to transform some of the kinetic energy of rotation into pressure energy, so as to reduce the vacuum effect. The dust outlet can be left open, or a closed receptacle can be attached.

TABLE 6—SUMMARY OF 1924 SERIES OF TESTS

No.	Make or Trade Name	Type	Dust-Separating Efficiency, Per Cent: Average of All Tests	Dust-Separating Efficiency, Per Cent: Service Run	Low Water	Abrasive Removed in Service Run, Per Cent	Vacuum at 20.4 Hp. and 1200 R.P.M.: Cleaner Clear	Vacuum at 20.4 Hp. and 1200 R.P.M.: 100 Grams of No. 1 Standard Dust
31	Twister	Dry	...	44.7	...	45.1	7/8	7/8
33	Case	Wet	96.7	97.4	94.6	97.7	2	2
35	Protectomotor C-4[b]	Dry	99.8	99.7	...	99.7	3/4	1 3/8
35A	Protectomotor C-4[b]	Dry	99.8	99.5	...	...	3/4	2 1/8
35B	Protectomotor C-4[b]	Dry	...	99.8	...	...	9/16	1 (50 grams)
36	Bennett	Oil	98.4	99.2	...	98.7	1 3/4	53 3/8
37	Bennett	Oil	...	98.9	...	99.2	5 9/16	29 3/4 (50 grams)
39	Simplex	Oil	98.7	97.5	...	97.2	15/16	11
40	Simplex	Oil	99.2	99.6	...	99.2	1 7/16	31
41	Hose	Dry	99.7	99.9	...	...	2 1/4	3 3/8
42	Gordon	Dry	99.9	99.9	...	99.8	3 1/8	5 7/8
43	Gordon	Dry	98.2	97.0	...	96.9	5 7/16	9 3/4
44	Winslow 10 In.[4]	Oil	98.4	98.6	...	98.5	2 5/16	2 5/16
45	Winslow 8 In.[4]	Oil	99.9	99.8	...	99.3	3 3/16	3 3/16
47	Turbo Automatic[5]	Dry	55.9	47.2	...	49.9	3	3
48	Cyclone Automatic[5]	Dry	62.7	74.9	...	76.8	3	3
49	Thompson[6]	Dry	24.0	9.6	...	7.7	5 1/2	5 1/2
49A	Thompson[6]	Dry	80.4	...	...	...	6	6
50	Donaldson, W.H.L.	Dry	88.0	...	...	...	3 3/8	51
51	Midwest	Oil	62.8	73.2	...	73.1	1 1/2	1 1/2
52	Dailey 7½ In.	Oil	99.9	99.8	...	...	4 7/8	6 1/8
53	Pomona No. 142	Oil	95.9	94.8	...	95.2	2	2
54	Palmer, A. E.	Dry	...	50.0	...	50.3	3 7/8	3 7/8

[b] The first two of these are almost exact duplicates, one furnished by the manufacturer, the other sent in by a buyer. The third is the same as the first except that it has no staples through single thickness of the felt.

[4] Each of these has a small air-inlet at the base to operate an air-lift type oil-pump.

[5] Each of these has a dust outlet about 1 in. in diameter. That on the first is conchiform; that on the second is the frustum of a cone. The tests run on these cleaners were special and unofficial. While No. 1 standard dust was used, the regular dust feed was not used.

[6] These have a centrifugal air-pump with a runner measuring 6.2 in. in diameter and 1 in. wide. The first has a 2.5-in. pulley for belt drive; the second is arranged for direct motor drive up to 6000 r.p.m.

Table 6 is a summary of the 1924 tests. Table 7 is presented for identification purposes. Table 8 lists the respective manufacturers of the cleaners.

In connection with Table 6, the following air-cleaners have not yet been tested: No. 32, Siphon, 1A, wet type; No. 55, White, oil type; No. 57, Simplex, oil type; and No. 58, Pomona, 161, oil type. References are made to the road tests in regard to air-cleaners No. 34, Wishon, dry type; No. 48A, Cyclone Automatic, dry type; and No. 56, I. & M. Perfection, dry type. The test of No.

TABLE 7—IDENTIFICATION OF AIR-CLEANERS

Number of Cleaner	Make or Trade Name	Type	Weight, Lb.: Clean Dry	Weight, Lb.: Ready for Use	Inside Diameter of Outlet, In.	Inlets: Number of	Inlets: Diameter or Size, In.	Body Proper: Height, In.	Body Proper: Length, In.	Body Proper: Width, In.	Body Proper: Diameter, In.	Materials: Body	Materials: Filter
31	Twister	Dry	0.7	0.7	1.90	1	3.00	....	4.0	....	3.8	Sheet Steel	None
32	Taco Siphon, 1A	Wet	45.6	56.2	1.75	2	0.50x1.50	12	15.0	6.0	....	Cast Iron	None
33	J. I. Case, TM	Dry	19.0	40.7	2.50	1	2.50	....	18.0	....	12.0	Sheet Steel	None
34	Wishon	Dry	1.3	1.3	1.70	25	0.05x1.75	9	5.0	0.5	....	Sheet Steel	None
35	Protectomotor, C-4	Dry	2.5	2.5	1.94	312	0.06x0.75	....	7.5	....	6.0	Spun Aluminum	Felt
35A	Protectomotor, C-4	Dry	2.4	2.4	1.94	312	0.06x0.75	....	7.5	....	6.0	Spun Aluminum	Felt
35B	Protectomotor, C-4	Dry	2.3	2.3	1.93	312	0.06x0.75	....	7.5	....	6.0	Spun Aluminum	Felt
36	Bennett	Oil	3.4	4.0[e]	1.90	1	2.00	....	3.5	....	6.5	Sheet Steel	Fiber
37	Bennett	Oil	2.9	3.2[e]	1.70	1	1.80	....	3.0	....	6.0	Sheet Steel	Fiber
38	Bennett	Oil	1.9	2.1[e]	1.40	1	1.50	....	2.6	....	4.5	Sheet Steel	Fiber
39	Simplex	Oil	3.3	4.1[e]	2.00	10	0.60x1.70	....	8.2	....	6.0	Sheet Steel	Fiber
40	Simplex	Oil	2.1	2.5[e]	1.90	10	0.60x1.70	....	8.0	....	4.0	Sheet Steel	Fiber
41	Hose	Dry	2.9	2.9	1.87	...	Sponge	12	9.0	4.5	....	Rubber	Rubber Sponge
42	Gordon	Dry	5.7	5.7	1.95	138	0.75	....	4.4	....	10.0	Sheet Steel	Rubber Sponge
43	Gordon	Dry	4.0	4.0	1.75	90	0.75	....	4.3	....	8.0	Sheet Steel	Rubber Sponge
44	Winslow, 10 In.	Oil	20.5	29.3	2.25	1	2.50	....	14.0	....	10.5	Sheet Steel	Fiber
45	Winslow, 8 In.	Oil	13.0	18.2	2.05	1	2.50	....	12.0	....	8.5	Sheet Steel	Fiber
46	Winslow, 6 In.	Oil	7.3	10.2	1.81	1	2.00	....	8.5	....	6.0	Sheet Steel	Fiber
47	Turbo-Automatic	Dry	3.4	3.4	1.88	1	5.52x6.50	14	....	3.0	....	Sheet Steel	None
48	Cyclone Automatic	Dry	3.4	3.4	1.88	1	4.75	....	9	....	8.5 6.0	Sheet Steel	None
48A	Cyclone Automatic	Dry	2.3	2.3	2.05	1	2.15	....	6	....	6.0 4.2	Sheet Steel	None
49	Thompson	Dry	6.1	6.1	1.60	1	1.55	....	2.5	....	1.0	Cast Aluminum	None
49A	Thompson	Dry	6.1	6.1	1.60	1	1.55	....	2.5	....	7.5	Cast Aluminum	None
50	W. H. L. Donaldson	Dry	3.1	3.1	1.75	1	1.77	....	8.5	....	8.0	Sheet Steel	Cloth Screen
51	Midwest	Oil	2.8	2.8	2.00	8	1.20	....	4.3	....	5.5	Spun Aluminum	Expanded Metal
52	Dailey, 7½ In.	Oil	4.8	5.8[e]	1.92	2	0.75x1.90	....	12.3	....	7.5	Sheet Steel	Fiber
53	Pomona No. 142	Oil	8.2	9.9	1.75	1	2.50	....	12.0	....	5.5	Sheet Steel	Wire
54	A. E. Palmer	Dry	6.8	6.8	1.88	1	1.70x11.10	....	11.0	....	11.2 4.6	Sheet Brass	None
55	White[7]	Oil	3.6	4.5[e]	1.56	8	0.63	5	9.0	5.0	....	Sheet Steel	Fiber
56	I. & M. Perfection	Dry	0.7	0.7	1.87	1	3.80	....	3.8	....	4.0	Pressed Steel	None
57	Simplex[8]	Oil	10.1	11.3[e]	1.87	1	3.00	....	8.6	....	7.0	Sheet St. & C. I.	Fiber
58	Pomona No. 161	Oil	8.1	10.0	1.66	1	2.50	....	12.0	....	5.5	Sheet Steel	Wire

[e] Estimated; it varies with the length of time of draining and with the kind of oil used.

[7] The cleaner is designed to replace the regular float and baffles in the Fordson air-washer shell.

[8] The weights include the cast-iron bracket and the 15-in. periscope; filter element similar to No. 39.

TABLE 8—MAKERS OF THE AIR-CLEANERS USED IN THE 1924 TEST SERIES

Company Name	Company Address	Air-Cleaners	
		Trade Name	Number
Bennett Carburetor Co.	101 First Avenue, North, Minneapolis	Bennett	36, 37, 38
California Sprayer Co.	5001 Pasadena Avenue, Los Angeles, Cal.	Dailey	52
J. I. Case Threshing Machine Co.	Racine, Wis.	T. M.	33
Donaldson Co., Inc.	693 Raymond Avenue, St. Paul, Minn.	Twister	31
		Simplex	39, 40, 57
W. H. L. Donaldson	4700 Aldrich Avenue, South Minneapolis		50
L. F. Dunn	Dinuba, Cal.	White	55
Gordon Air-Cleaner Co.	1336 Broadway, Kansas City, Mo.	Gordon	42, 43
Hose Air Cleaner Co.	1336 Broadway, Kansas City, Mo.	Hose	41
Midwest Air Filters, Inc.	100 East 45th Street, New York, City.	Midwest	51
A. E. Palmer	1610 Elberon Avenue, East Cleveland, Ohio		54
Ireland & Mathews Co.	Detroit	Perfection	56
Staynew Filter Corporation	Rochester, N. Y.	Protectomotor	35, 35A, 35B
E. S. Thompson	Porterville, Cal.	Thompson	49, 49A
Tractor Appliance Co.	New Holstein, Wis.	Taco Siphon	32
Vortox Mfg. Co.	Pomona, Cal.	Pomona	53, 58
Winslow Carburetor Co.	Vallejo, Cal.	Winslow	44, 45, 46
		Turbo Automatic	47
		Cyclone Automatic	48, 48A
Ralph Wishon	61 Perry Street, San Francisco.	Wishon	34

38, Bennett, oil type, is not yet complete. That of No. 46, Winslow 6 in., was inconclusive; it also has a small air-inlet at the base to operate an air-lift type oil-pump, as for Nos. 44 and 45. Air-cleaner No. 48A has a dust outlet about 1 in. in diameter, formed like the frustrum of a cone, as for No. 48.

Oily Filter Type

The Bennett cleaners, Nos. 36, 37 and 38, differ only in size. The air is admitted by a tangentially placed opening into a cylindrical sheet-metal shell having its axis horizontal. A narrow slit at the bottom enables dust whirled to the periphery to escape into a glass receptacle. The partially cleansed air enters the outer curved surface of the cylindrical oily-fiber filter in which it gets its final cleansing.

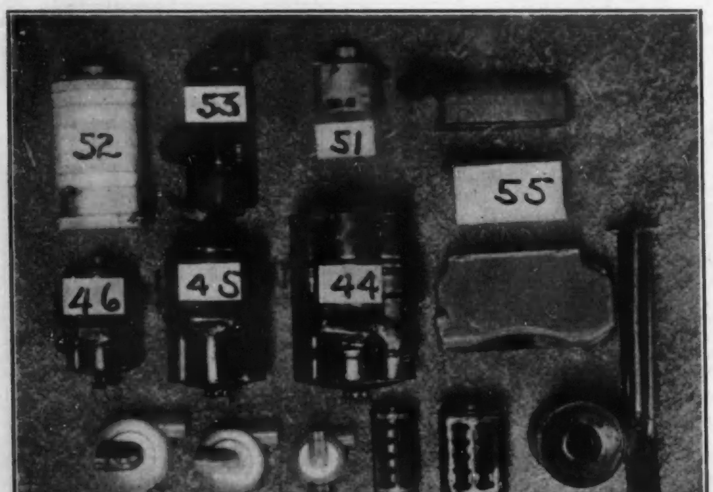

Fig. 8—The Oil-Filter Type Cleaner
The Bennett Cleaners Nos. 36, 37 and 38, Differ Only in Size. The Simplex Cleaners, Nos. 39, 40 and 57, Are of the Same General Design, Nos. 39 and 40 Differing Only in Size, While Nos. 40 and 57 Have the Same Size Filter Element, but the Former Is Designed Primarily for Passenger Cars or Trucks and the Latter for a Certain Tractor. The Winslow Cleaners, Nos. 44, 45 and 46, Differ Chiefly in Size. The Midwest, No. 51, Consists of a Group of Expanded or Perforated Metal Plates through Which the Air Rises. The Dailey, No. 52, Has a Cylindrical Filter of Oiled Organic Fibers Enclosed in a Sheet-Metal Shell, the Air Passing Up from the Bottom. In the Pomona Cleaner, No. 53, the Air Entering through a Tangentially Placed Inlet Sprays on a Fine-Wire Filter, Keeping It Washed Clean of the Dust Left Behind by the Air in Its Upward Passage through the Filter. The White Cleaner, No. 55, Has a Rectangular Filter of Oiled Organic Fibers in a Sheet-Metal Shell and Is Designed To Replace the Float and Baffles of the Fordson Tractor Air-Washer

Simplex cleaners Nos. 39, 40 and 57 are of the same general design, Nos. 39 and 40 differing only in size. Nos. 40 and 57 have the same size of filter element, but differ in that the former is designed primarily for automobile or truck use and the latter for a certain tractor. The cylindrical shell is evidently mainly for the support and protection of the filter element, which consists of a hollow cylinder of oiled organic fibers. The air enters through punched holes in the shell and passes from the outer to the inner curved surface of the filter.

Winslow cleaners Nos. 44, 45 and 46 differ mainly in size. Air is admitted by a tangentially placed inlet that descends spirally to beneath the level of the oil in the cup forming the base of the cleaner. The spray of oil caused by the whirl washes a coarse outer screen of perforated metal through which the air must pass on its way to a second inner screen having smaller openings; and the filter of oiled organic fibers is in the shape of an inverted frustrum of a cone. The inner screen and the filter are washed by a stream of oil carried up from the cup below by a simple air-lift pump. Air for this pump enters the cleaner by a separate inlet but must pass through the filter before going to the carbureter air-intake.

The Dailey cleaner, No. 52, has, in a sheet-metal shell, a cylindrical filter of oiled organic fibers through which the air passes vertically from the bottom. The entrance to the shell is by two tangentially placed openings opposing each other. The purpose is to permit the slip-stream from the radiator fan to throw out some of the dust as the air entering the cleaner whips around the edges of the openings.

Pomona cleaners Nos. 53 and 58 differ principally in the quantity of filter material they contain. These cleaners are the same in principle as No. 20 of the 1922 series. The six-direction-outlet ell-connection is the principal difference. The air entering by a tangentially placed inlet sprays oil up onto the filter of fine wire, keeping it washed clean of dust left behind by the air passing up through the filter.

The White cleaner, No. 55, is a rectangular filter of oiled organic fibers in a sheet-metal shell designed to go inside the shell of the regular Fordson-tractor air-washer, replacing the regular float and baffles.

The Midwest cleaner, No. 51, consists of a group of expanded or perforated metal plates through which the air passes from the bottom upward. Before use, the plates are coated with oil or some other viscous or sticky solution.

Acknowledgments

I am indebted to a large number of persons and corporations for very material assistance in the work. All the cleaners tested were loaned. Officials of the Rickenbacker Motor Co. and Ralph Wishon placed cars at our disposal for the road tests. Engineers in several universities and commercial organizations furnished valuable suggestions. Prof. C. S. Bisson and Prof. J. G. Sewell, of the Division of Chemistry, made the determinations of abrasives. The cooperation of the entire Agricultural Engineering staff of the University of California enabled the early completion of the work. Grateful acknowledgment is hereby extended.

Proposed Constitutional Amendments

AT the Semi-Annual Meeting held at Spring Lake, N. J., in June, three amendments to the Constitution of the Society were presented. The first of these, which was offered at the Business Meeting on June 24, relates to the designation of the Sections Committee, and the others, which were presented at the adjourned session of the Business Meeting that was held on June 26, have to do with the qualifications for membership in the Society.

In compliance with Constitutional provision, the proposed amendments will be submitted to each voting member of the Society and will be discussed at the Annual Meeting that is to be held next January. After discussion and final amendment at that meeting, the amendments will be submitted by letter-ballot on adoption to all members entitled to vote, provided 20 votes are cast in favor of such submission.

The portions of the paragraphs of the Constitution which it is proposed shall be amended are given below, the matter that would be omitted if the amendments submitted were adopted being printed in brackets, with the new passages that would be substituted in italics.

C 2 The object of the Society is to promote the Arts and Sciences and Standards and Engineering Practices connected with the design, [and] construction *and utilization* of [automobiles] *automotive apparatus,* all forms of self-propelled or mechanically propelled mediums for the transportation of passengers or freight, and internal-combustion prime-movers.

C 8 Member grade shall be composed of persons 26 years of age or over, who by previous technical training or experience or by present occupation are qualified to act as designers or constructors of complete automotive apparatus or their important component parts; or to exercise responsible technical supervision of the production of materials germane to the construction of automotive apparatus; or to take responsible charge of automotive engineering work, *including operation or maintenance;* or to impart technical instruction in the design, [and] construction *and utilization* of automotive apparatus; or who by reason of distinguished service or noteworthy accomplishment would, in the discretion of the Council, appear to be desirable additions to this grade.

C 45 The President shall, within 30 days after taking office, appoint, from the individual membership of the Society, the following Committees, designating the Chairman thereof:

Finance Committee, consisting of five members.
Meetings Committee, consisting of five members.
Publication Committee, consisting of five members.
Membership Committee, consisting of five members.
House Committee, consisting of five members.
[Sections Committee, consisting of five members.]
Tellers as required by the By-Laws.

There shall be also an administrative committee of the Society called the Sections Committee. This committee, the members of which shall serve for 1 year, during the administrative year, shall consist of one member of the Society to be elected from and by each Section of the Society each year prior to the Annual Meeting of the Society, and three members of the Society who shall be appointed by the President within 30 days after he takes office. The President shall name the Chairman of the Committee.

There shall be also a standing committee of the Society called the Constitution Committee, consisting of three members, one of whom shall be appointed by the President within 30 days after taking office, for a term of 3 years. The member who shall have but 1 year yet to serve shall be the chairman.

The Discussion at the Meeting

A report of the discussion at the adjourned Business Session when the amendments to C 2 and C 8 were proposed follows.

R. E. Plimpton:—Most of you will remember that Past-President Manly about 2 years ago called our attention to the fact that the operating end of the business would be a big thing in the future. Since that time we have taken in as members a number of men associated with operating companies who have no interest in manufacture or design primarily. We have welcomed these men. We have had papers from some of them. I think that the time has come when we ought to recognize their value to the Society and encourage their coming in by having a definite statement in the Constitution, so that our position will be clear.

I find in getting these men to come in, as I do very frequently, that when they read the requirements in the Constitution they say that there is no place for them and that they do not belong with us. The officers of the Society, by the meetings that they have authorized and by their general position have, I think, recognized that there is a place for these men. The purpose of the amendments which I shall read is simply to give effect to the idea I have expressed.

The first will be an amendment to C 2 which gives the object of the Society. As amended here, the first sentence of this section will read:

> The object of the Society is to promote the Arts and Sciences and Standards and Engineering Practices connected with the design, construction and utilization of automotive apparatus, all forms of self-propelled or mechanically propelled mediums for the transportation of passengers or freight, and internal-combustion prime-movers.

The new thing there is the addition of the words "and utilization" and the change of the present word "automobiles" to "automotive apparatus." That is obviously needed, I think.

Then further down is another amendment to C 8. This section now reads in part

> ...to take responsible charge of automotive engineering work or to impart technical instruction in the design and construction of automotive apparatus;

It is proposed that this clause of C 8 be amended to read

> or to take responsible charge of automotive engineering work, including operation or maintenance, or to impart technical instruction in the design, construction and utilization of automotive apparatus;

You will note that in the second amendment, the word "utilization" is elaborated somewhat and a reference made to operation or maintenance. I think that was done purposely so that the men who are with operating companies in executive positions, and directly concerned with the construction or the design of automobiles, would feel that there is a place for them in the Society, and in addition that there would be a place for a large number of men connected with manufacturers and dealers.

(*Concluded on p. 162*)

Laboratory Strength-Tests of Motor-Truck Wheels

By Tom W. Greene[1]

Illustrated with Photographs and Drawings

[C 54 The Society shall not be responsible for statements or opinions advanced in papers or in discussions at its meetings]

FREQUENTLY, it is desired to obtain comparative data concerning the strength and other physical properties of motor-truck wheels when it is not expedient to obtain the information direct from service tests, which require a large expenditure of money and time. During the war the Bureau of Standards, in cooperation with the Quartermaster Corps of the Army, devised and conducted a series of laboratory tests on truck wheels which proved of value. The results of these tests are described in Bureau of Standards Technologic

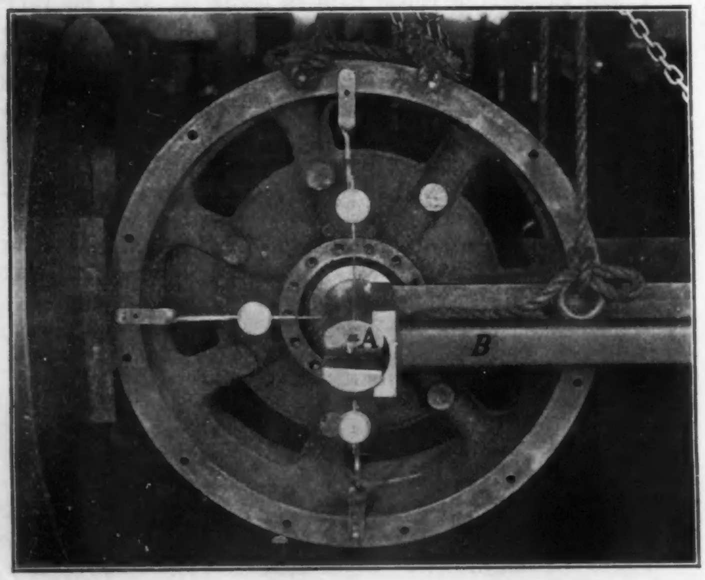

Fig. 1—Radial-Compression Test of Motor-Truck Wheels
In Making This Test the Wheel Was Placed on the Short Axle *A* Which Was Supported on Both Sides of the Wheel by the Bearing Blocks *B*. The Load Was Applied through a Block at the Rim to a Portion between Spokes and Was Distributed over the Full Width of the Rim and along an Arc of 6 In. The Deformation of the Wheel between the Rim and the Axle Was Measured by Four Dial Micrometers, Only Three of Which Can Be Seen

Paper No. 150, entitled "Physical Tests of Motor-Truck Wheels." Since that time the Bureau of Standards has tested for the Holabird Quartermaster Intermediate Depot, Motor Transport Corps, different types of motor-truck wheel which are used on its 3- and 5-ton Class-B trucks. Although the tests described here cannot completely replace service tests, they undoubtedly are of interest and value in supplementing service tests.

Wheel Requirements

The requirements listed below were considered essential in a wheel, and the tests were conducted so that information concerning these requirements might be obtained.

[1] Assistant engineer-physicist, Bureau of Standards, City of Washington.

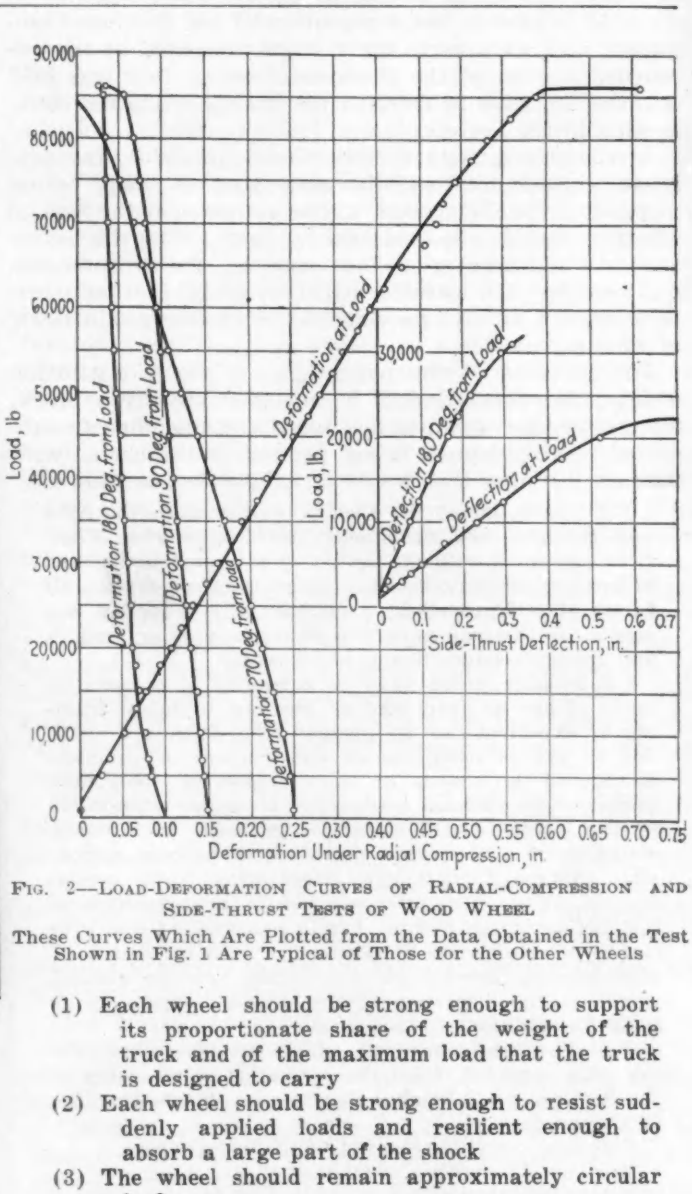

Fig. 2—Load-Deformation Curves of Radial-Compression and Side-Thrust Tests of Wood Wheel
These Curves Which Are Plotted from the Data Obtained in the Test Shown in Fig. 1 Are Typical of Those for the Other Wheels

(1) Each wheel should be strong enough to support its proportionate share of the weight of the truck and of the maximum load that the truck is designed to carry
(2) Each wheel should be strong enough to resist suddenly applied loads and resilient enough to absorb a large part of the shock
(3) The wheel should remain approximately circular in form
(4) The wheel should be capable of sustaining stresses due to side-thrust. These may be introduced by skidding, by turning or by running on roadways that are crowned or have a side slope
(5) The weight of the wheel should be as low as possible without reducing the strength of the wheel below that of other parts of the truck

Types of Wheel

In this investigation 12 wheels were tested, consisting of the following types of rear wheel, two of each: Class-B truck, standard wood; Class-B truck, cast-steel; I-beam type; steel-disc; aluminum; and rubber-cushion. All the wheels were standard, having a 34-in. diameter and a 12-in. tread. The cast-steel wheels had 7 spokes. The standard wood-wheel, the I-beam type of wheel and the

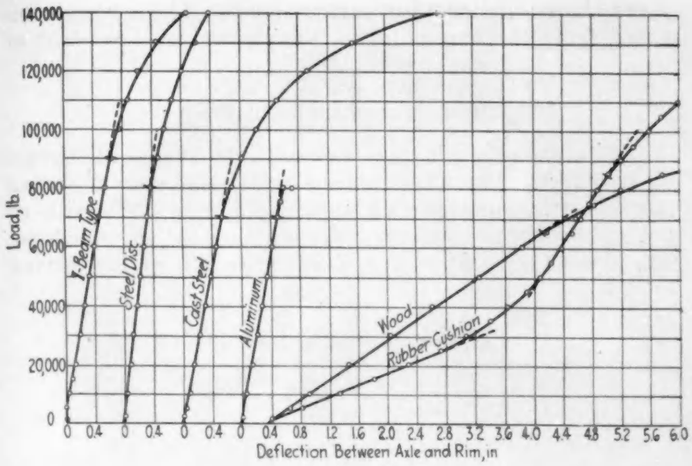

FIG. 3—LOAD-DEFORMATION CURVES OF RADIAL-COMPRESSION TEST OF MOTOR-TRUCK WHEELS

These Curves Furnish a Ready Means for Comparing the Deformation between the Axle and the Rim for the Six Types of Wheel Tested

cushion wheel each had 14 spokes. The aluminum and the steel-disc wheels had a solid web between the hub and the rim. The general construction of these wheels is shown in the illustrations. All the wheels were tested without tires or brake-bands and were bushed to fit a 4-in. axle. The area of contact between the hub and the bushing was the same as that in service. The Bureau of Standards Emery hydraulic testing-machine, having a capacity of 2,300,000 lb., was used for both the radial-compression and the side-thrust tests.

RADIAL-COMPRESSION TEST

One wheel of each type was subjected to a radial-compression test. For this test the wheel was placed on a short axle, *A*, as shown in Fig. 1. This axle was supported on both sides of the wheel by bearing-blocks *B*. The load was applied through a block at the rim. This block distributed the load over the full width of the rim and along an arc of 6 in. The wheel was placed so that the load was applied to a section of the rim between spokes. The deformation of the wheel between the rim and the axle was measured by four dial-micrometers attached to the rim. The data obtained from these tests are shown in Figs. 2 and 3, plotted as load-deformation curves. The results of the radial-compression tests are given in Table 1.

TABLE 1—RESULTS OF RADIAL-COMPRESSION TEST

		Type of Wheel					
		Standard Wood	Cast-Steel	I-Beam	Steel-Disc	Aluminum	Rubber-Cushion
Weight, lb.		308	400	389	445	204	625
Proportional Limit, lb.		65,000	70,000	90,000	80,000	70,000	85,000
Deformation at Proportional Limit, in.		0.370	0.055	0.068	0.040	0.050	0.465
Ratio of Proportional Limit to Weight		211	175	232	180	343	136
Load at Which Micrometers Were Removed	Load, lb.	86,000	155,000	148,000	200,000	80,000	190,000
	Deformation, in.	0.658	1.028	0.665	0.479	0.069	1.217
Maximum Load, lb.		95,000	185,000	148,000	203,000	100,000	211,000
Slope of Load-Deformation Curve, lb. per in.		173,000	1,275,000	1,320,000	2,000,000	1,400,000	101,000[a] 370,000[b]
Elastic Resiliency	Resiliency, in-lb.	12,350	1,960	2,880	1,600	1,750	14,390
	Resiliency per Pound of Metal in the Wheel, in-lb.	40.0	4.9	7.4	3.6	8.6	23.0

[a]This value results from the deformation of the rubber cushion.
[b]This value is due to the deformation of the wheel after the rubber cushion has been deformed enough to allow the inner and the outer rims to come into contact.

PROPORTIONAL LIMIT

The proportional limit, that is, the limit of proportionality of deformation to load, is one of the most important factors that can be determined by test, not only because the rate of deformation does not remain constant beyond that point but also because the wheel becomes permanently deformed if higher loads are applied. The wheel should not only have sufficient strength to withstand the loads but should be as light as possible. The wheels constitute a large part of the unsprung weight, so this should be kept as low as possible in order that the wear and tear on both the truck and the road will be minimized. The ratio between the proportional limit and weight or specific strength is a good index of the value of the wheels.

The maximum applied loads were those at which the wheels were either broken or crushed beyond any possible use. The slope of the load-deformation curve is the rate of deformation between the axle and the rim under load; it is an index of the stiffness of the wheel, a high value indicating a wheel that deforms but little for loads below the proportional limit.

ELASTIC RESILIENCY

A very important factor that should be considered in determining the efficiency of a wheel is the elastic resiliency or the ability to absorb shock. This value represents the energy that the wheel can absorb without permanent injury. The elastic resiliency should be large to minimize the effect of the unsprung weight, thus prolonging the life of both the truck and the road. The elastic resiliencies of the wheels have been computed from these tests for the point of application of the load and recorded in Table 1. The area under the load-deformation curve from zero load to the proportional limit was here considered.

The elastic resiliencies recorded in Table 1 afford a good means for comparing the different types of wheel. They should not be used, however, without carefully considering the other qualities of the wheels at the same time. Large elastic resiliency is desirable, but it may be large only because of the high proportional-limit of the wheel and not because of large elastic deformation. In such cases the resiliency would be small at the loads to which the wheel is ordinarily subjected. The resiliencies at low loads were, therefore, computed. Table 2

TABLE 2—RESILIENCIES FOR VARIOUS LOADS—RADIAL-COMPRESSION TEST

Load, Lb.	Resiliencies for Wheels, In-Lb.					
	Standard Wood	Cast-Steel	I-Beam Type	Steel Disc	Aluminum	Rubber-Cushion
5,000	63	10	10	10	7	100
10,000	250	40	35	20	30	450
15,000	567	90	83	45	75	1,050
20,000	1,070	160	150	80	140	1,850
25,000	1,688	225	238	125	225	2,875
30,000	2,475	330	335	210	315	3,725
35,000	3,415	455	473	280	437	4,885
40,000	4,500	600	600	400	600	5,720

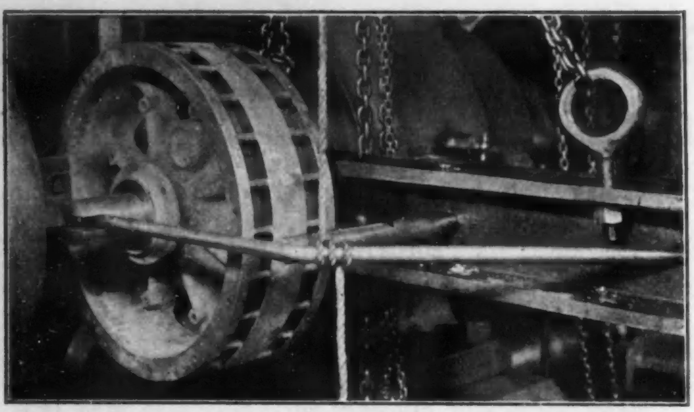

FIG. 4—WHEELS BEING SUBJECTED TO A SIDE-THRUST OR SKID TEST
The Wheels Were Mounted in the Testing Machine as Shown and the Load Applied to the Rim through the Block C

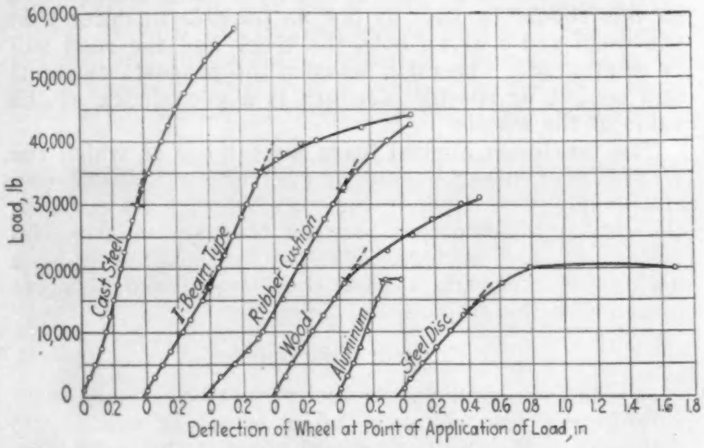

FIG. 5—LOAD-DEFLECTION CURVES FOR THE SKID TEST
These Results Were Obtained with the Set-Up Shown in Fig. 4. The Values from Which the Curves Were Plotted Are Given in Table 3

gives the resiliencies for various loads. These were computed from the load-deformation curves for the point at which the load was applied.

SIDE-THRUST OR SKID TEST

One wheel of each type was subjected to a side-thrust or skid test. The wheel placed on the axle was mounted in the testing machine as shown in Fig. 4. The side of the H-beam was supported by one head of the machine. The axis of the axle was parallel to the axis of the testing machine and, therefore, was parallel to the direction of the applied load. This load was applied to the side of the rim of the wheel at point *c*, through a block 6 in. wide. To measure the deformation of the wheel under load, micrometer dials were fastened between the H-beam and the side of the rim of the wheel at the point where the load was to be applied, and at a point diametrically

TABLE 3—RESULTS OF SIDE-THRUST OR SKID TEST

		Type of Wheel					
		Standard Wood	Cast-Steel	I-Beam	Steel-Disc	Aluminum	Rubber-Cushion
Proportional Limit, lb.		18,000	30,000	35,000	13,000	18,000	32,000
Deformation at Proportional Limit, in.		0.44	0.35	0.72	0.39	0.28	0.82
Ratio of Proportional Limit to Weight		58	75	90	29	88	51
Maximum Load, lb.		40,000	57,000	45,500	27,000	23,000	64,000
Slope of Load-Deformation Curve, lb. per in.		39,000	102,000	58,000	30,000	64,000	44,000
Elastic Resiliency	At Load, in.-lb.	4,230	4,815	11,890	2,800	2,610	12,060
	At 180 deg. from Load, in.-lb.	1,700	2,630	4,940	1,400	1,350	6,000
	At Load per Pound of Metal, in.-lb.	13.7	12.0	30.6	6.3	12.8	19.3

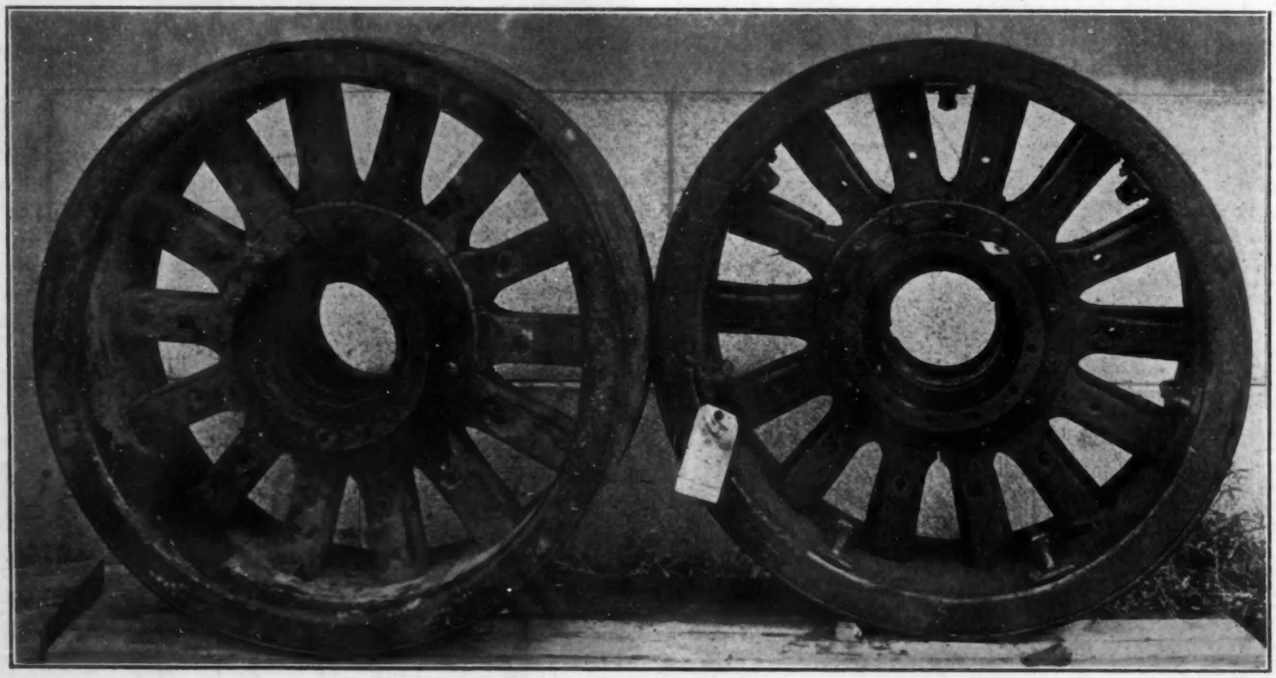

FIG. 6—APPEARANCE OF THE WOOD WHEEL AT THE CONCLUSION OF THE TESTS
The View at the Left Shows the Wheel That Failed in the Side-Thrust Test. In This Wheel the Spokes on the Load Side Were Broken at the Hub as a Result of the Bending of the Wheel. Three Spokes Located 180 Deg. from the Point of Application of the Load Were Split. The Wheel at the Right Failed in the Radial-Compression Test. At a Load of 85,000 Lb., the Spoke Adjacent to the Loading Point Failed in Compression and at a 95,000-Lb. Load the Adjacent Spoke Failed. The Rim Was Forced Inward at the Point of Application of the Load and Away from the Spokes at a Point Diametrically Opposite

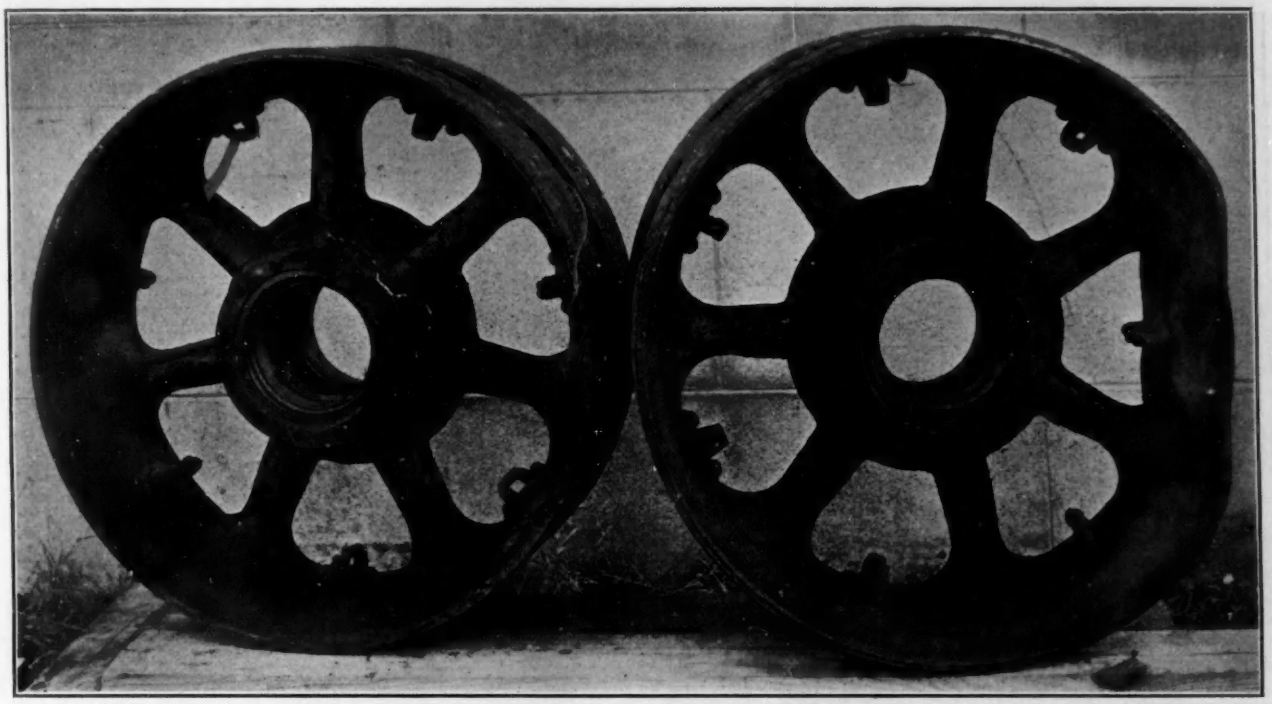

FIG. 7—HOW THE CAST-STEEL WHEEL LOOKED AT THE CONCLUSION OF THE TESTS
The Wheel at the Left Failed in the Skid or Side-Thrust Test, the Casting Cracking near the Hub at the End of All the Spokes on the Load Side of the Wheel. The Wheel at the Right was Subjected to the Radial-Compression Test. At a Load of 155,000 Lb. the Rim Was Deformed Inward at the Load Point, Causing the Rim To Crack in Tension on the Hub Side. When the Load Was Increased to Its Maximum Value of 185,000 Lb., the Rim Was Deformed Inward Causing the Crack To Open

opposite. Load-deflection curves for the skid test were plotted, and are shown in Fig. 5. The results of this test are given in Table 3.

CHARACTER OF FAILURE

Photographs illustrating the failure of each wheel are reproduced in Figs. 6 to 11. A brief description of the failure is given with each photograph. In practically every case, failure in the side-thrust or skid test occurred in the spokes or in the web near the hub. This was to be expected because of the large bending-moment at that place.

SUMMARY AND CONCLUSIONS

A comparison of the important mechanical properties of the six different types of wheel is shown graphically in the curves of Figs. 12 and 13. The results of these tests appear to warrant the following conclusions:

FIG. 8—THE I-BEAM WHEEL AFTER UNDERGOING THE TESTS
The View at the Left Shows the Wheel That Failed in Radial Compression. The Rim Was Somewhat Deformed at the Point Where the Load Was Applied and the Two Adjacent Spokes Buckled in Compression. The Wheel Shown at the Right Failed in the Side-Thrust Test. Two Spokes Running to the Inside of the Hub from the Vicinity of the Point at Which the Load Was Applied Began To Buckle at a Load of 38,000 Lb. At a Load of Approximately 45,000 Lb. Two Bolts Holding the Spokes to the Hub Failed in Shear, Causing the Adjacent Bolts To Fail in Tension at the Threaded Section

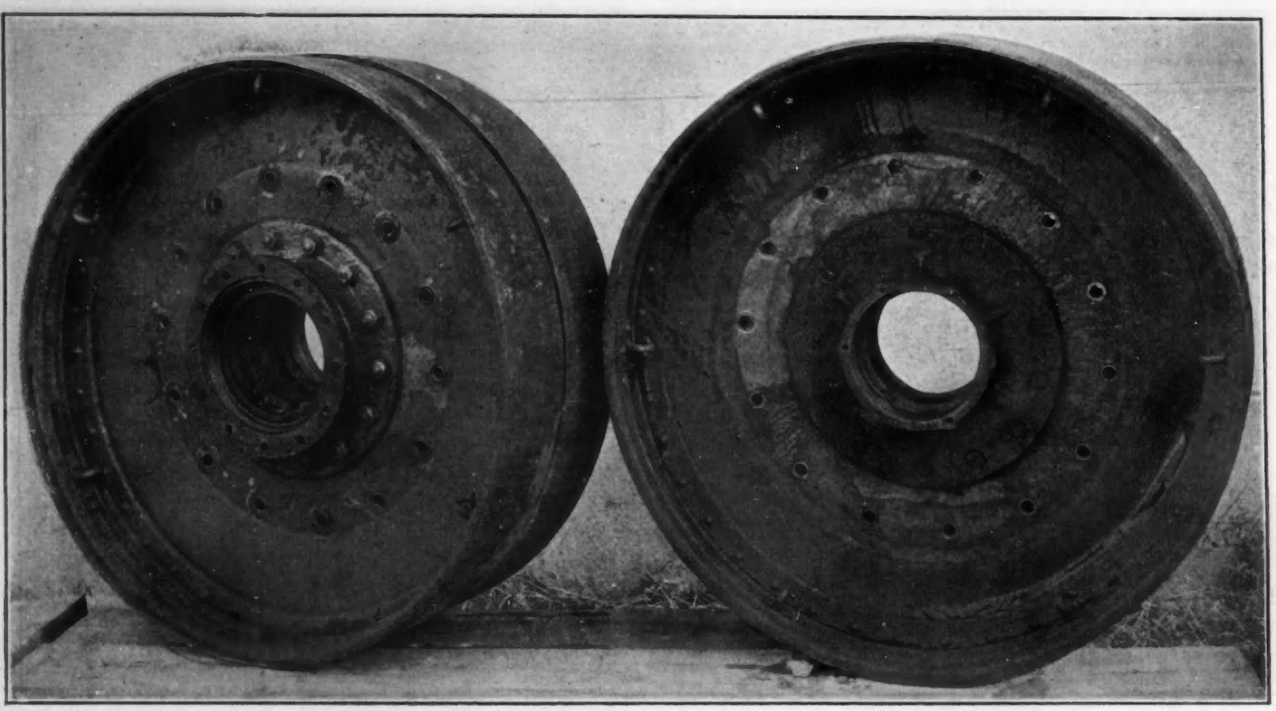

FIG. 9—APPEARANCE OF THE STEEL-DISC WHEEL AFTER THE TESTS
The Wheel at the Left Failed in Side-Thrust, the Failure Occurring by the Bending of the Entire Wheel Which Caused a Pronounced Displacement of the Two Halves of the Wheel. This Wheel Was Weak To Resist Skid because of Insufficient Bracing To Prevent Displacement of the Half Section. At the Right Is Shown the Wheel That Failed in Radial Compression. At Low Loads the Hub Sheared toward the Rim and at the Maximum Load of 203,000 Lb. the Web Buckled and the Rim Split at the Rivet Fastening the Rim to the Web

(1) In radial compression, all the wheels are undoubtedly sufficiently strong to withstand any load to which they might be subjected in service, and it is improbable that any of these wheels would ever be stressed even to its proportional limit. If any of these wheels were to fail in service, this probably would be due to side-thrust or skidding; so, this latter test is relatively more important than the radial-compression test for a comparison of the wheels and indications of weakness in the design

(2) Taking into consideration the proportional limit, the specific strength and resiliency developed in both the radial-compression and the side-thrust tests, the results indicate that the wood wheel probably is the best adapted for motor-truck service. Although the other wheels developed considerably higher ultimate-strength, especially

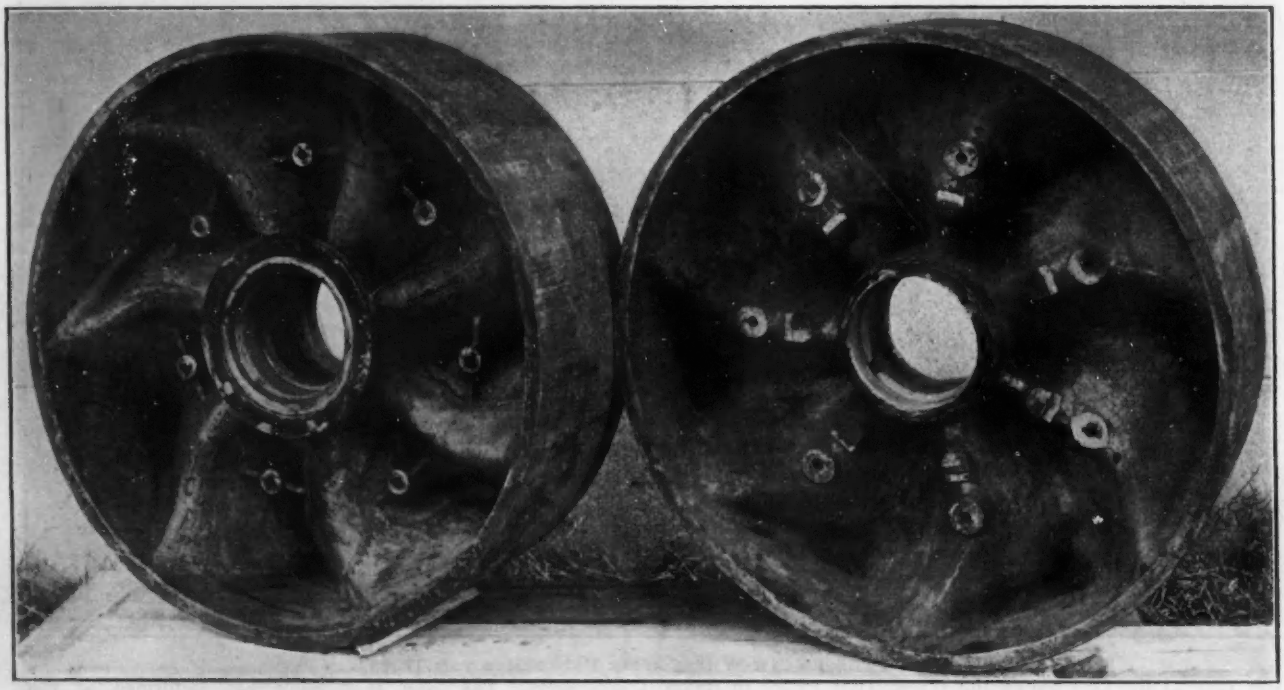

FIG. 10—HOW THE ALUMINUM WHEEL LOOKED AT THE CONCLUSION OF THE TESTS
The View at the Left Shows How the Wheel Failed in the Side-Thrust Test, the Web Cracking near the Hub on the Load Side of the Wheel. In the Radial-Compression Test the Wheel at the Right Failed at a Load of 80,000 Lb., the Web Cracking from the Hub to the Rim at the Load Point. When the Load Was Increased to 100,000 Lb. the Crack Opened

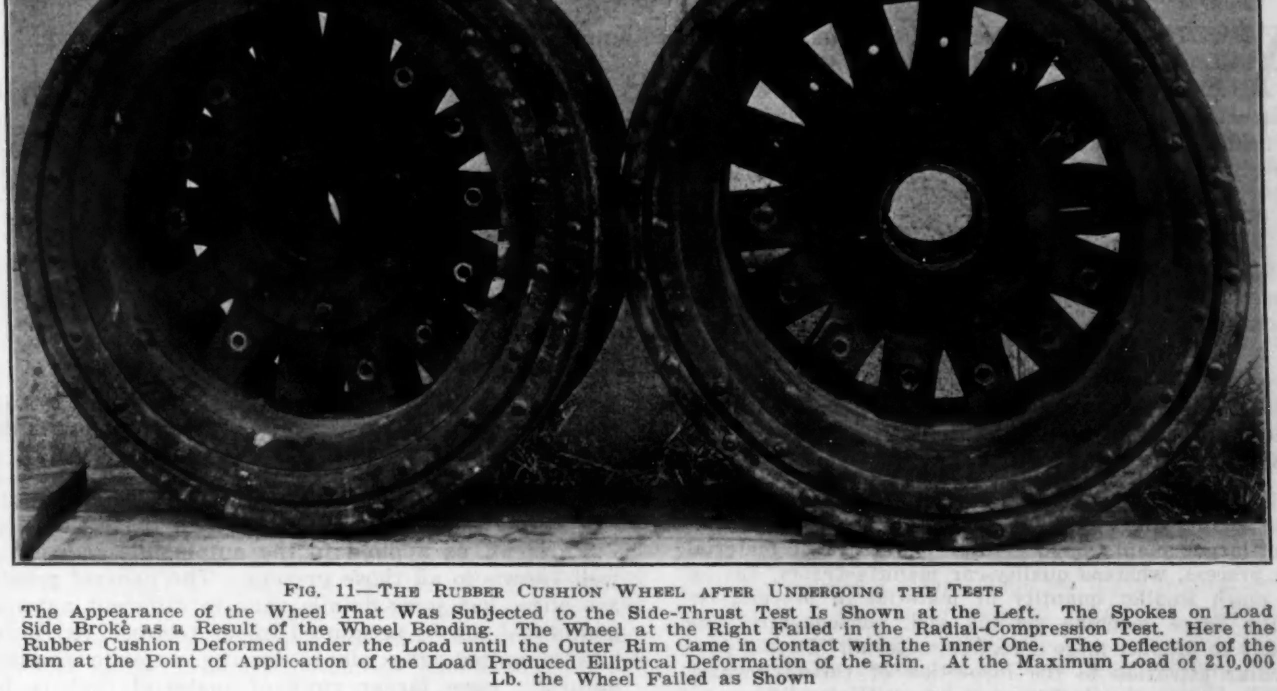

FIG. 11—THE RUBBER CUSHION WHEEL AFTER UNDERGOING THE TESTS
The Appearance of the Wheel That Was Subjected to the Side-Thrust Test Is Shown at the Left. The Spokes on Load Side Broke as a Result of the Wheel Bending. The Wheel at the Right Failed in the Radial-Compression Test. Here the Rubber Cushion Deformed under the Load until the Outer Rim Came in Contact with the Inner One. The Deflection of the Rim at the Point of Application of the Load Produced Elliptical Deformation of the Rim. At the Maximum Load of 210,000 Lb. the Wheel Failed as Shown

the cast-steel and the special steel-disc wheel, the proportional limit of the wood wheel is only about 20 per cent less than that of any of the other wheels. The proportional limit is of relatively greater importance than the ultimate strength because, if the wheel is stressed above the proportional limit, the wheel becomes permanently deformed, and this would tend to render the wheel unserviceable. The specific strength, that is, the proportional limit divided by the weight, is higher for the wood wheel than for the others, except in the case of the aluminum wheel. The elastic resiliency and the elastic resiliency per pound of weight of the wheel are also very much higher for the wood wheel than for the others; about 700 per cent greater than for any of the metal wheels

(3) The I-beam type of wheel was the strongest and most resilient metal wheel tested. Except for

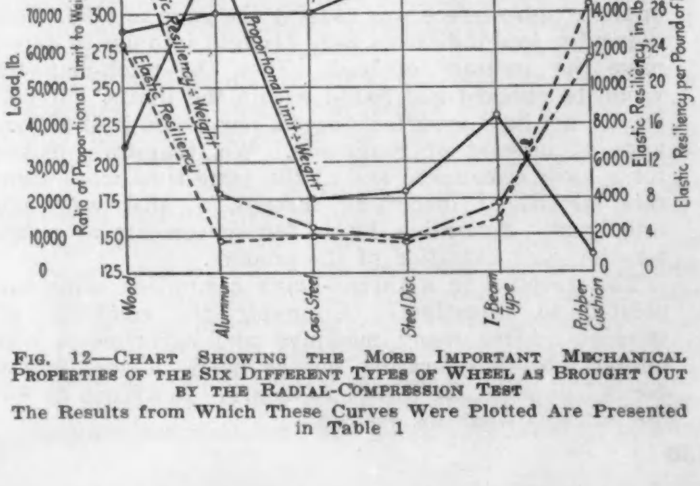

FIG. 12—CHART SHOWING THE MORE IMPORTANT MECHANICAL PROPERTIES OF THE SIX DIFFERENT TYPES OF WHEEL AS BROUGHT OUT BY THE RADIAL-COMPRESSION TEST
The Results from Which These Curves Were Plotted Are Presented in Table 1

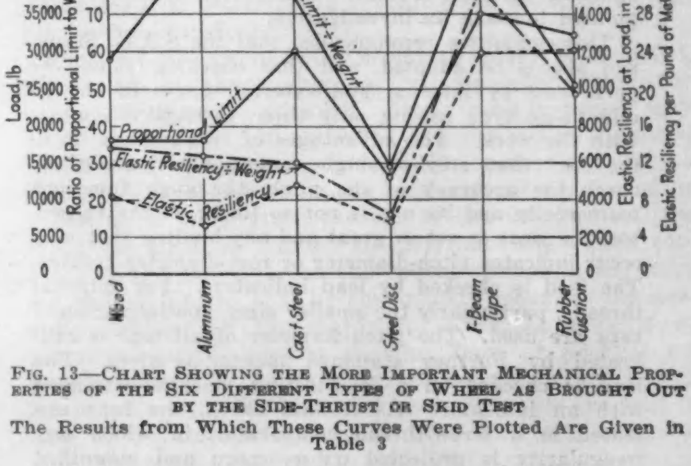

FIG. 13—CHART SHOWING THE MORE IMPORTANT MECHANICAL PROPERTIES OF THE SIX DIFFERENT TYPES OF WHEEL AS BROUGHT OUT BY THE SIDE-THRUST OR SKID TEST
The Results from Which These Curves Were Plotted Are Given in Table 3

resiliency, it compares very favorably with the wood wheel. This wheel had the highest proportional limit. The specific strength was higher than that of any other, except the aluminum wheel. The resiliency and the resiliency per pound were higher for the I-beam type of wheel than for any other metal wheel; to resist side-thrust or skid, this wheel is the strongest and most resilient

(4) The aluminum wheel was the lightest one tested, being about 30 per cent lighter than the wood wheel. The proportional limit in radial compression was about the same as that of the other wheels; but, because of its light weight, the specific strength was the highest. However, this wheel has a very low elastic resiliency and low strength in side-thrust

(*Concluded on p. 174*)

Inspection Methods Symposium

A MEETING of the Detroit Section, held in the General Motors Building, Detroit, on April 17, 1924, was devoted to the reading of several papers, a discussion of the importance of accurate inspection and the need of cooperation between the engineering and the production departments, and suggestions both for improving the quality of the material produced and for decreasing the cost of the inspection process.

Papers were contributed by C. S. Stark, A. H. Frauenthal and C. J. Jones. Each of these papers is presented in full in this issue. A report of the active discussion that followed the reading of the papers will appear later.

A FEW HIGH POINTS ON THE INSPECTION OF PROCESSED MATERIAL

BY C. S. STARK[1]

[C 54 The Society shall not be responsible for statements or opinions advanced in papers or in discussions at its meetings]

DETAILS of inspection vary in different automobile plants and can be accounted for by the fact that the larger plants have greater quantities of material in process, whereas quality-car manufacturers, having a much smaller quantity of material in process, require more machine set-ups and, consequently, are likely to produce more defective material. Paying particular attention to the inspection of threads, which previously to the design of the first Packard-Six consumed an unusual amount of time and labor because of the special standards and special taps and dies needed, and with a view to finding a more economical and at the same time more accurate method of inspecting threads, a thread-limits committee was appointed to make an investigation.

This committee recommended that the S.A.E. Standard should be adopted, and that checking should be performed by internal and external gages of the go and no-go type having only three threads in contact with the work. The advantages of this method lie in the fact that only a single movement is needed to check the accuracy of the pitch, the gage functions more easily and its use is not so tiring on the inspector, the wear is not so great and any binding that may occur indicates pitch-diameter or root-diameter trouble. The lead is checked by lead indicators. For internal threads, particularly the smaller sizes, specially-ground taps are used. The pitch-diameter of all taps is calibrated by Fortney standard measuring-wires. The lead is checked on a lead-testing machine equipped with an indicator. As a final check, the taps are placed in a screw-thread comparator, in which any irregularity is projected on a screen and magnified 200 times.

For the economical inspection of large quantities of small parts, such as machine screws, the stock to be inspected is spread out on a bench so that the general condition of the material may be visualized. By examining pieces at random, the exact percentage of defective work can be determined. This percentage varies with the part. If a percentage greater than that considered allowable is found, the lot is subjected to detail inspection. Inspectors have only one function to perform and that is to separate the work before them strictly in accordance with the gages, or to examine for defects visually in accordance with the standards supplied to them. They are not allowed to use any judgment whatever. The responsibility of disposing of dead material is vested in a committee of three men, consisting of the mechanical superintendent, the general superintendent of manufacturing and the chief inspector, who visit certain departments each day according to a schedule.

THE value of inspection, the method of its application and the functioning of an inspection department, as applied to the automobile industry, are well known to all those present. The general principles are alike, but some details vary in different automobile plants and can be accounted for as follows: (*a*) automobile manufacturing plants having a large production naturally have larger runs of material that is being processed and (*b*) quality-car manufacturers, who naturally do not have large production, must of necessity possess material in small quantities, with the result that more machine set-ups are required and, consequently, more defective material is produced.

One of our "high spots" is the inspection of threads. As we all know, the present form and type of threads are not all that they should be, but, as they are necessary evils, we must make the best of them. We experimented with many different methods of gaging in the inspection of threads. External and internal "go" and "no-go" gages, lead indicators, projectors and many other types of specially constructed gage for checking both the pitch and the lead were used, but each of them became very expensive.

Previous to designing the first Packard-Six, the detail inspection of all screw parts involved an unusual amount of time and labor. At that time we had our own thread standard and, consequently, purchased special taps and dies. Our internal and external go and no-go thread gages contained approximately 10 to 14 threads, but with this type of gage it was impossible to determine whether the pitch-diameter, the root-diameter, the lead or the rough surface was causing the gage to bind. Consequently, lead indicators were brought into use to determine the accuracy of lead. Then the pitch-diameter would be checked and found within the limits, but still we did not have a perfect thread, nor would it enter our gage on account of roughness. We, therefore, looked for a more economical and at the same time more accurate method of inspecting threads, so that we could intelligently determine, by as few movements as possible, the exact condition of the product.

This resulted in a thread-limits committee being appointed to investigate thoroughly the condition of threads. After many meetings and experiments and taking into consideration service parts, it was finally decided to adopt the S.A.E. Standard. A wrench fit for the nut was what we desired.

[1] Chief inspector, Packard Motor Car Co., Detroit.

Go and No-Go Gages

It was finally decided that the thread gaging for this new standard should be performed by internal and external gages of the go and no-go type, having only three threads in actual contact with the work. By one movement, therefore, we can immediately check the accuracy of the pitch, not by a point contact as with snap gages, but by a cylindrical check, taking it for granted that a little variation in the lead of three threads is of no material disadvantage. We also found that this type of gage functions more easily and is not so trying on the inspector. At the same time, the wear is not so great as that of the 10 or 14-thread gage, which wears bell-mouthed very quickly. With this three-thread type of gage, we have very little binding and any that may occur immediately indicates pitch-diameter or root-diameter trouble. These gages are marked "Go" and "No-go", as well as with the pitch-diameter and the number of threads per inch.

After having determined that the cylindrical pitch checks with our go and no-go gages, we use lead indicators to check the lead. We use various types of lead indicator. For ordinary machine-screws a tolerance of 0.003 in. per in. is allowable. On all work, however, on which the engagement is more than 1 in. of thread, we allow a tolerance of 0.0015 in. per in. This system of inspection for external threads has materially reduced the number of inspectors engaged in this type of inspection and better products reach the assembling departments.

On internal threads, however, particularly in the smaller sizes, under 3/8 in., we aim to take care of the work by using specially ground taps. These taps are calibrated strictly within our tolerance, with regard both to lead and to pitch, and are also examined very carefully by a shadow comparator. Any tap that is not strictly within our requirements is not used. On these taps we hold the pitch-diameter to a plus 0.000 minus 0.0005 limit and the lead to 0.0005 in. per in. We find that these ground taps produce very dependable internal threads of correct lead, and from them produce a threaded hole of uniform diameter. Occasionally, in ground taps, we find that the flutes have an unequal cutting-power. To guard against using these in production, the inspection covers the actual tapping of a number of holes.

Taps Calibrated by Three-Wire Standard

In addition to this test, we calibrate the pitch-diameter of all taps by the three-wire standard. For this inspection, the Fortney standard measuring-wires are used. We check the lead on the Sheffield lead-testing machine, which is equipped with a Deming precision-indicator, Johannsen blocks being used instead of the micrometer head, and gives a positive zero-reading for any pitch of thread.

As a final or master check, the taps are placed in a Hartness screw-thread comparator and the pitch-diameter, angle of thread, lead or any irregularity is clearly shown when projected on a screen and magnified 200 times. This method is merely a check against the question of feel or sense of touch that we must have at all times when using the other method of gaging, for the picture that we see before us checks our previous findings. This method of thread inspection has been in force for approximately 3 years and, with our general and detail inspection, a description of which will follow, is giving us better results than our previous method.

I should like to say at this time that I believe the tap-and-die manufacturers are cooperating and progressing with a desire for a more accurate type of thread. They are supplying the trade with a very creditable product and have reduced most of our thread troubles by the grinding process. I hesitate to say as much for the machine-tool designers and builders and I doubt very much whether they have really given this matter the serious thought that they should give it. I feel that it is wrong to attempt to use taps in various machine-tools and make no provision whatever for maintaining the lead. We see that we allow considerable friction or resistance to take place when we figure the load that the tap carries, when dragging along turrets, tools or any other mechanism.

We have the so-called thread milling machine. The type of machinery I have in mind is the hand-tapping machine, automatic screw-machine, hand-screw machine and the like. We still have considerable food for thought and opportunity for improvement in the general problems of threads and the gaging of threads, and I should like very much to hear the experiences at other automobile plants along similar lines.

General Inspection

We have adopted another economical method for the inspection of large quantities of small parts as, for instance, machine screws and such parts as are not in the so-called precision class. This we term general or detail inspection. The term general takes the place of the so-called percentage inspection.

To perform general inspection properly and arrive at the exact condition of the work as a whole, we must adhere strictly to certain definite rules. This is by no means a new method; it is used by the Government in inspecting grain and in laboratory tests of material. We apply this method to small parts with wonderful results; it has assured better parts reaching the stockrooms and the assembling departments.

First of all, competent inspectors must be selected, who must be thoroughly coached in determining the quality of this type of work. Stock to be inspected may be in lots of from 100 to 50,000, but instead of the usual practice of determining a positive percentage to be checked, and to overcome the tendency merely to scrape a panful of work from the top of the original lot, the inspector must be trained to distribute the entire contents of the container on the bench, spreading the work out before him so that he can quickly visualize the general condition of the material. Then, by picking up pieces here and there at random, from an area of approximately 1 sq. in., and inspecting them carefully in accordance with the blueprint and the gages, he will be able to determine very quickly the exact percentage of defective work contained in each lot.

Allowable Percentage of Defective Work

It then becomes merely a problem of determining what percentage of defective work shall be allowed to reach the stockrooms. As an illustration, we will say that on undersize nuts, a percentage of 1 would not materially affect the efficiency of an assembling department, because the assembler could not start the nut. Consequently, work of this kind is allowed to pass and is accepted on this general inspection principle without further examination. If, however, it is found to contain a percentage greater than this, a skilful man immediately sets it aside and does not accept it. It is later sent to another inspector to be given a detail inspection. This work can be performed by a cheaper grade of inspector, preferably a woman, who examines each piece and separates the pieces in accordance with the required standards.

It is obvious that it is unnecessary to set a definite percentage of work for the general inspector to examine. Sometimes 100 pieces out of 50,000 is sufficient to determine accurately the exact contents of the lot. If the method, as explained above, is conscientiously followed, it can be determined very easily whether the work must be detailed, but it is to be understood that merely scraping off parts from the top of the container, without inverting the entire container and spreading the work out, is not an accurate proceeding.

We discontinued our set or definite percentage inspection in favor of, as we term it, our general inspection, and the results have been very marked, both as to the quality of the parts reaching the stockrooms and as to the economical side, the reduction of the number of inspectors heretofore performing the work.

Responsibility for the Disposition of Defective Material

From experience, we have found that it is very difficult to train a great number of inspectors along the line of so-called quality judgment; in other words, to allow them to exercise their own judgment with regard to parts not strictly up to set standards. We therefore adopted a plan several years ago by which our inspectors, in a sense, are denied the power of exercising any judgment whatever. On the other hand, they are trained to consider the dimensions and limits set forth on the blueprints, together with the gages supplied, to be as far as their judgment is to be exercised. They have just one function to perform, namely, to separate the work before them strictly in accordance with the gages supplied to them, or to examine visually for defects, in accordance with the visual standards supplied to them. Any variations from these are considered sufficient for the rejection of the part. Consequently, the separation is made intelligently and the parts removed from the lot are identified by the necessary forms that the inspector fills out, giving the various defects. Then, so far as he is concerned, his work is complete. All defective material is placed on a special bench in each department in which the inspectors are located and becomes dead material for the time being.

We adopted this method, not with a desire to eliminate from our organization the inspector who thinks, but because we wished him to understand that he can think only in terms indicated by our blueprints and gages. We teach him to think along intelligent lines only in the terms represented by the blueprints. We have found many inspectors that take upon themselves the responsibility of passing work that is not in accordance with the gages and drawings before them, with the thought in mind that 0.0015 in. is immaterial and should not give trouble; this condition also applies to the foremen of the inspection cribs. But the method described does away with the various standards created by individuals, that do not make for a standard product.

The responsibility for disposing of dead material is vested entirely in a committee of three men, consisting of the mechanical superintendent, the general superintendent of manufacturing and the chief inspector. Once a day, this committee visits certain departments that have been designated on a schedule, with a definite time-period consuming practically 2½ hr. each day. When this committee reaches a department, it examines all the rejected material, notes the defects recorded on the tags attached and immediately decides as to the final disposition of the material. In this way the mechanical superintendent is in close touch with the condition of the tools, and the superintendent of the division gets a good picture of the condition of his departments. The chief inspector makes the disposition, as the final judgment of parts that are not strictly in accordance with our limits is limited to one person. He may decide that the material can be repaired; that the defect may be so minute that the part can be accepted as it is; or he may indicate that it shall be mutilated in order that it cannot reach an outside source through junk dealers, after it has been sold as scrap material.

INFLUENCE OF NUMEROUS HANDLINGS ON INSPECTION COST

BY A. H. FRAUENTHAL[2]

[C 54 The Society shall not be responsible for statements or opinions advanced in papers or in discussions at its meetings]

TRANSPORTING and handling the material constitute a large part of the expense of inspection. The cost of transportation has not been considered in this paper, but only the time consumed in picking up and laying down gages and parts. A test made of the time required to scleroscope cam rollers by two different methods, in one of which the hammer was operated by a hand-bulb and in the other by a foot-pedal, showed that the former method requires 7.8 sec. per piece, the latter 6.0 sec., a saving of 30 per cent. Multiple gages that check several different parts simultaneously avoid many of the slighter movements.

But gages of this type are practicable only when they have been carefully designed and adapted to the part involved. Solid go and no-go gages are successful only when a large majority of the parts are correct. They do not indicate exact defects and should be reserved for small light parts and careful inspectors. When the tolerance is more than plus or minus 0.003 in. the flush-type indicator or "flush-button" gage is said to have proved very satisfactory. Their use in the multiple inspection and checking of water-pumps is described, as is also a fixture for checking the spiral gear on the camshaft and its mating gear on the oil-pump in ordinary camshaft inspection. Doubling up of inspection cuts down the initial gage-cost and makes unnecessary the picking up or the laying down of the camshaft or the oil-pump gear.

[2] Chief inspector, Chandler Motor Car Co., Cleveland, Ohio.

ONE of the largest expense items in the parts inspection of an automobile plant is that incident to the transporting and handling of the material to be inspected. In this paper the transportation of material to the inspector does not come under discussion, as such transportation is seldom under the control of the inspection department. It is important to note, however, that this cost is fundamentally one of inspection, for, were inspection eliminated, this cost would also be eliminated.

In the inspecting of parts requiring the observation

of more than one item or dimension, the gaging method often requires the use of a number of individual gages. When this is the case, it generally follows that a number of moves, each involving a certain amount of time, are required merely for picking up and laying down the gages and parts.

Comparative Time-Study

To demonstrate the high cost of these moves we made a comparative time-study involving two different methods of scleroscoping cam rollers, one of which eliminates some very short moves. In one method the scleroscope hammer is operated by a hand-bulb, in the other by a foot-pedal. Each roller is scleroscoped in four places on the periphery, thus requiring the operator to rotate the roller through approximately 90 deg., four different times. When using the bulb method, the left hand operates the clamp, while the right hand operates the bulb and also rotates the piece. The right hand constantly grasps the bulb but the operator cannot squeeze it while his hand is in the position to turn the roller. This necessitates a move of approximately 2 in. to get the hand into a suitable position for squeezing the bulb and takes place four times with each roller.

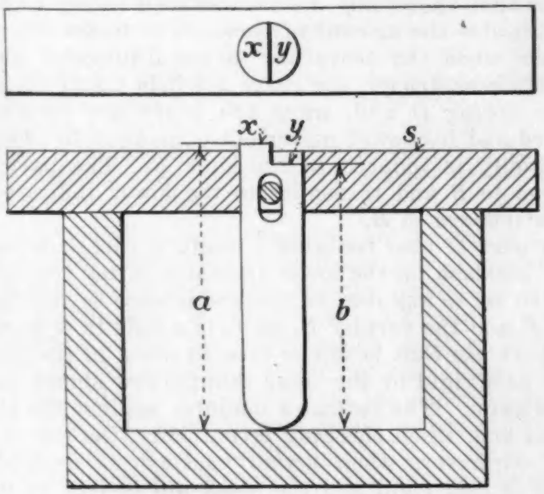

Fig. 1—A Simple Type of Flush-Pin or Flush-Button Gage
This Gage Consists of a Sturdy Pin Having a Tolerance Step Ground on One End and Is Used in Connection with a Ground Surface on the Piece within Which the Pin Moves. A Gage of This Type Is Used where the Tolerance Is in Excess of Plus or Minus 0.003 In. The Distance *a* Corresponds to the Low Limit and the Distance *b* to the High Limit. When the Part Being Checked Is on the Low Limit the *x* Side of the Pin Is Flush with the Ground Surface *s* and when the Part Being Checked Is on the High Limit the *y* Side of the Pin Is Flush

With the foot-pedal method this extra movement is avoided, as is also the necessity for releasing the bulb when loading and unloading with the right hand. These advantages result from the freedom of both hands to manipulate the specimen and the clamp.

We found that an experienced operator requires 7.8 sec. per piece by the hand-bulb method and 6.0 sec. by the foot-pedal method. We therefore show a saving of 30 per cent.

Multiple Gaging

The economy gained by avoiding the slighter movements noted above makes it highly desirable to attack the larger movements associated mainly with the picking up and the laying down of gages and parts. This can be accomplished by the use of multiple gages that check several different points simultaneously.

Gages of this type, however, are practicable only when they have been carefully designed and adapted to the part involved. Solid "Go" and "No-Go" gages of this type are not a commercial success except when a large majority of the parts are correct. Their weakness lies in the fact that they do not indicate the exact defect in the part. The only information gained is that the part is not correct, since it does not fit the gage, and the inspector must then recheck it to determine the exact trouble. The inflexibility of this type of gage is particularly embarrassing when it is desirable to salvage a quantity of material containing a certain defect, provided all the other dimensions are correct. The fact that one dimension is at fault makes it impossible to inspect the part farther.

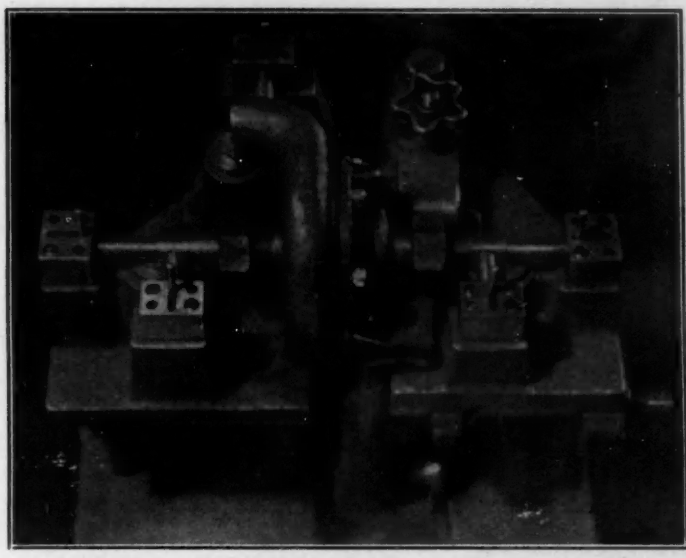

Fig. 2—An Application of This Type of Indicator to Multiple Inspection
This Particular Fixture Is Being Used for Checking Water-Pumps and Checks 10 Different Items, All of Which Can Be Off Considerably More than Commercial Possibilities and Still Be Checked by This Gage

This difficulty may be overcome by replacing the rigid gaging-points with indicators of one type or another but, if the tolerances are small, requiring dial or compound lever-type indicators, the result is often a gage that will be too delicate for ordinary use. Gages of this type should be reserved for small light parts and careful inspectors.

Fig. 3—The Fixture Illustrated in Fig. 2 with Pump Removed
The 10 Points on the Water-Pump That Are Checked by this Fixture Can Now Be Readily Seen

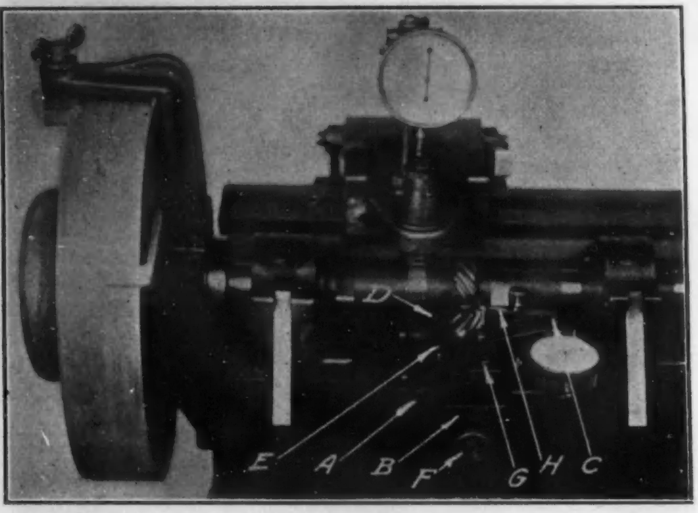

FIG. 4—FIXTURE USED FOR CHECKING THE SPIRAL GEAR ON THE CAMSHAFT AND ITS MATING GEAR ON THE OIL-PUMP AS WELL AS FOR ORDINARY CAMSHAFT INSPECTION

When Camshaft Gears Are Being Checked a Master Oil-Pump Gear Is Used on the Fixture and when the Oil-Pump Gears Are Being Checked a Camshaft Containing a Master Gear Is Used. The Casting *A* Is Rigidly Fastened to the Bed of the Camshaft Fixture. The Casting *B* That Bears the Oil-Pump Gear Is Dovetailed into *A* and Is Free To Move Toward or Away from the Camshaft and Is Held Toward the Camshaft by the Spring *D*. By Turning the Thumb-Screw *F* the Slide *B* and Hence the Oil-Pump Gear Can Be Maintained at Any Desired Distance from the Camshaft Gear. Any Desired Center Distance Is Secured by Manipulating the Vernier *E* Which Also Indicates the Amount of Backlash in Terms of the Center Distance when the Gears Are Making Metal-to-Metal Contact

Flush-Pin Gages

When the tolerance is more than plus or minus 0.003 in. the flush-type indicator or "flush-button" gage has proved very satisfactory. This gage consists merely of a sturdy pin with a tolerance step ground on one end and is used in connection with a ground surface on the piece within which the pin moves.

A simple type of this gage is shown in Fig. 1. The distance *a* corresponds to the low limit and the distance *b* to the high limit. When the part being checked is on the low limit, the *x* side of the pin is flush with the ground surface *s*; when it is on the high limit, the *y* side of the pin is flush.

It may be well to note here that 0.002 in. above or below flush can easily be detected by running the finger across the indicating end and that, by virtue of this fact, we are provided with a gage of low initial cost that embodies sturdiness, durability, ease of replacement and simplicity of operation. It can be used by anyone having the sense of touch, for calculations or sight readings are unnecessary. The application of this type of indicator to multiple inspection is shown in Fig. 2.

This fixture is used for checking water-pumps; 10 different items, all of which may be off considerably more than commercial probabilities, can still be checked by it. In Fig. 3 we have the fixture without the pump and the 10 points are clearly shown.

Camshaft-Gear Inspection

Very many present-day engines have the oil-pump driving-gear integral with the camshaft. This design lends itself admirably to multiple inspection, as a very complete gear-checking fixture is readily applied to a conventional camshaft-checking fixture. The fixture shown in Fig. 4 is used for checking the spiral gear on the camshaft and its mating gear on the oil-pump, as well as for ordinary camshaft inspection. When camshaft gears are checked a master oil-pump gear is used on the fixture, and when oil-pump gears are checked a camshaft containing a master gear is used.

The casting *A* is rigidly fastened to the bed of the camshaft fixture. Casting *B*, which bears the oil-pump gear, is dovetailed into *A*, is free to move toward or away from the camshaft and is held toward the camshaft by the spring *D*. The slide *B*, and hence the oil-pump gear, can be maintained at any desired distance from the camshaft gear by turning the thumbscrew *F*. At *E* is a vernier that allows any desired center-distance to be set and indicates the amount of backlash in terms of center-distance when the gears are in metal-to-metal contact. To check eccentricity, the gears are held tightly together by the spring *D* and, when the gears are revolved, a forward and backward movement equivalent to twice the eccentricity is induced in the slide *B*. The part *G* is fastened to *B* and transmits to the lower indicator the motion induced in *B*.

The part *G* also contains a feature for showing the actual backlash on the lower indicator, after the slide *B* has been set to any desired center-distance by the thumbscrew *F* and the vernier *E*. At *C* is a hole in *G* in which is a short pin that is either free to move in the hole or can be held rigid by the small thumbscrew shown behind the indicator. The indicator operates against the end of this pin and, when checking eccentricity, the pin is held rigid. However, when actual backlash is desired the slide *B* is held rigid and the small pin is free to move; one end of the lever *H* is brought into contact with a gear tooth; the other end, with the movable pin. Thus, when the pinion is moved through the backlash the motion of the gear tooth is transmitted to the indicator.

Advantages of This Method

The doubling-up of inspection in this manner cuts down initial gage-cost and makes unnecessary a separate operation. The actual movements thus avoided are the picking up and the laying down of the camshaft or the oil-pump gear, as the case may be. An idea of the amount of labor saved can be gained by comparing the magnitude of the movements eliminated in this case with the magnitude of the movements eliminated in the example of scleroscoping.

MAINTAINING HIGH-QUALITY PRODUCTION

BY C. J. JONES[3]

[C 54 The Society shall not be responsible for statements or opinions advanced in papers or in discussions at its meetings]

INSPECTION can be maintained only through the cooperation of the engineering and the production departments and is insurance against defective material entering the product. Production alone cannot maintain the close standards of precision and accuracy that are demanded in products of the better grade. With "quality" the watchword, effort is made to have all parts correct before they are passed on to sub and major assemblies. Parts not up to standard must be rejected. Defective material is called to the attention of the head of the department and he is held responsible for seeing that the defects do not recur. By holding the head of the department, as well as the

[3] Chief inspector, Lincoln Motor Co., Detroit.

head inspector, responsible, two endless chains of inspection are provided.

To get men of the right caliber it is sometimes necessary to take them from the production departments where they have been in charge of particular lines. Instead of being a loss, scrapping the parts that are not up to standard puts those concerned on their toes, makes the workmen more efficient, and in the end results in a saving. Vendors who have been unable to work up to the required standards have been shown how to do so.

All parts received are given a 100-per cent inspection, including metallurgical, visual, heat-treating, pickling and Brinell tests. Aluminum crankcases are made with test-bars attached for testing. Every detail in the engine assembling department is watched, from the machining of the component parts to the final test, as is also every operation on the chassis, from the time the frame starts on the line until all the parts have been assembled complete. The complete chassis is then tested by men who have had considerable experience and is rechecked later to make sure that all repairs have been made. Before being loaded for shipment it receives another test and any needed additional adjustments are made or defects corrected. At the loading-dock the car is washed and receives another inspection to ascertain whether all tool-kits and parts are intact. Electrical equipment obtained from outside manufacturers is checked with precision instruments, any part rejected being returned to the vendor. All painting materials are furnished to the body builders after having received every known test in the paint test-room.

IT is impossible for inspection to maintain a high quality of production without the best of cooperation between the engineering and the production departments. Inspection is insurance that the motor-car manufacturer buys as a protection against defective material or workmanship entering his product. The modern manufacturer realizes that the reputation of his product and the value of his trade name, which may represent millions of dollars, depend to a large extent on rigid inspection. Experience has demonstrated conclusively that production alone, especially the high-speed production characteristic of the automobile industry, cannot maintain the close standards of precision and accuracy that builders and buyers of the better grade product demand.

The policy adopted from the beginning by our organization and passed down from the head officials to the smallest department head is, "Quality is the first word in the organization." It has also been impressed upon the various production department heads that they should look to the quality of their work and see that all parts are correct before they are passed on to sub and major assemblies. If parts are not up to requirements they must be rejected instead of passed through; "passing the buck" to the next department is thus avoided. In this way we get the best cooperation between the department heads. The percentage of rejections in the final inspection in all departments is also cut down. We have a rule that the final inspector in each department must make it his business to point out all defective workmanship to the head of that department, who is held responsible for seeing that the same complaint is not made again.

The slogan that our organization has impressed upon the various department heads is, "Is it good enough for you?" In other words, the idea of quality is always drilled into all the men in their departments. In this way, every man takes pride in his work, makes it "Good enough for him," and does not pass it along to the inspector until this result has been accomplished. In holding the head of each and every department responsible for the work going out of his department, just as we do the head inspector of each department, we have two complete units of inspection, in other words, two endless chains. In addition, we have inspectors that we use as "trouble-shooters" in each division.

It has been generally known that, in the average plant, it is very hard for the inspection department to get the proper backing to turn out the best possible product. This is not true in our organization; hence, it is very easy for us to maintain the best possible quality. There are and probably always will be cases where it remains for the head of the inspection department to make a final decision when it is hard for others to decide; in other words, when the part may be either passed or rejected. In our plant, in cases of this kind, we follow the policy of rejection rather than give our customers a product that may prove unsatisfactory.

Selecting Inspectors

In selecting men for inspection work, we always canvass the plant to pick out the best material. To get a man of the right caliber, it is sometimes necessary to take him from the production organization, where he has been in charge of work that makes him familiar with every operation in that particular line.

We work hand in hand with the engineering department and insist upon every part being made according to specifications. This applies to specifications for material as well as for manufactured parts. In some cases this policy makes it necessary to scrap material or parts that are not up to the engineering specifications; but we find in the long run that this rights itself very readily; instead of being a loss, it gets all those concerned on their toes, makes more efficient workmen and in the end is a saving. We have had outside vendors say that it was impossible to work to our requirements. In some of these cases we have sent a man to their plants to get them started on manufacturing to the standard of quality that we insist on maintaining. These same manufacturers have come back later, stating that the stand we took had made better workmen in their organizations.

Because of the limited time allowed, with your permission I shall hit merely the "high spots" of our inspection from the time the material is received until it has been shipped. All parts received are given a 100-per cent inspection. For instance, all material used in forgings is inspected by the metallurgist before it is released at the steel-mill to go to the forge-shop. Upon receiving the forgings at the forge-shop the metallurgist makes another laboratory test, selecting forgings at random. The forgings are then pickled to disclose any defects, are given a complete visual inspection, as well as checked for form, and are heat-treated and repickled to uncover any defects that may have been overlooked in the first inspection or have been caused by the heat-treatment. All forgings are then given a complete Brinell-test before they go to the machine-shop. In many cases we run another Brinell-test during the process of machining.

All castings, such as aluminum crankcases, have a test-bar anchored to them. This is tested in the laboratory before a crankcase, for example, is machined in order to see that the metal is up to specifications. Throughout the plant we insist on having detailed inspection of all parts between operations. This cuts to the minimum the chances of defective parts getting through the final inspection; it also stops further work on parts that are defective.

Supervision of Details

In the engine-assembling department, in order to build an engine that will give the owner complete satisfaction, our inspection department has gone to the extreme limit of inspection in watching the assembling from the machining of the component parts to the final test. This consists of the running and the static balancing of the crankshafts, flywheels and clutch rings and the weighing and balancing of connecting-rods, piston-rings and the like. We have numerous inspections of bearings by the rigid dynamometer, on which each engine is run under a heavier load than it will ever be called upon to exert under average conditions. After this test each engine is opened and again inspected for any unusual wearing of surfaces. An indicator-reading is taken of each bearing. As a final test, some of the engines are picked at random and run to test the fuel-consumption and endurance. After these tests the engines are again disassembled and checked with precision instruments to note any wear that may have occurred. It would appear to most persons that the last tests mentioned should be unnecessary because of our not having had one failure.

Every operation of the chassis is followed closely by inspection from the time the frame starts on the line until the engine and all the parts have been assembled complete. The chassis is then tested by men who have had considerable experience. These testers work under the supervision of the head of the engine and chassis assembly, as well as the inspection office. Any lining-up and adjustments required are recorded by these testers and later taken care of by expert repairmen. The chassis then receives another check to be sure that the repairs have been made.

After the body has been mounted, the complete car receives another test by another set of testers. Any adjustments or defects reported by them are then corrected by another set of repairmen. After that, the car is given a very rigid visual inspection and, if found o.k., goes to the loading-dock, is washed and receives another inspection to make sure that the car has been properly washed and cleaned and that the tool-kits and all parts are intact, making the car complete. The car is then loaded under the supervision of the man in charge of the loading-dock and the head inspector on the loading-dock, who are held jointly responsible for the loading and the checking of the car before the box-car doors are closed and sealed.

Electrical Equipment

It is a well-known fact that very few motor-car manufacturers will guarantee electrical equipment that is supplied by outside manufacturers, relying entirely upon the makers of this equipment. In most cases the electrical supplies are received from the vendor and assembled without inspection. We have made it a rule from the beginning to inspect each unit or part of the electrical equipment completely with precision instruments. Any part that does not measure up to our standard is rejected and returned to the vendor. We find that in this way electrical trouble is reduced to the minimum. The electric wiring in the bodies is checked at the body plants and is also checked before the bodies are mounted on the chassis at our plant.

The Building of Bodies

At all our body plants we have first-class body-builders, as well as men of long experience in the painting trade, supervising the building of all the bodies. All bodies receive a complete inspection at the outside plants before they are shipped to us. To keep outside companies from using inferior material in the painting of our bodies, all paint material from the priming to the final coat is furnished to the body-builders from our plant. The paint material received at our plant is given every known test.

PROPOSED CONSTITUTIONAL AMENDMENTS

(*Concluded from p.* 149)

These men are doing important work in both service and transportation lines.

I therefore propose these amendments for the consideration of the Members.

PRESIDENT H. M. CRANE:—The motion has been presented in due form for this amendment. Is it seconded?

CORNELIUS T. MYERS:—I second it very enthusiastically.

PRESIDENT CRANE:—According to the Constitution, I now declare the motion seconded and open for discussion. No question is involved at this time. If no discussion is desired, the further Constitution-Amendment steps will be taken, the proposal being transmitted to the voting members 60 days' before the 1925 Annual Meeting, at which it will come up for final discussion and amendment. I take it that that is your desire.

A report of the remarks made in connection with the presentation of the amendment to C 45 follows.

J. H. HUNT:—A special committee was appointed by the Council several months ago to consider the conditions in the Sections. That committee made a report with which you are all familiar. That report was referred to the present Sections Committee, which has reported back to the Council. The Council has endorsed the proposition of changing the Constitution to provide for a new organization of the Sections Committee.

The Constitution, at present provides for a Sections Committee of five to be appointed by the President each year. Our present Sections Committee is larger than that, as the President has seen fit to appoint a representative from each of the Sections. The recommendation of the Special Committee, which has been endorsed by the Sections Committee, provides for the following changes in the Constitution:

> In C 45 delete the words "Sections Committee, consisting of five members."
>
> Insert the following before the last full paragraph of the present C 45:
>
> > There shall be also an administrative committee of the Society called the Sections Committee. This committee, the members of which shall serve for 1 year, during the administrative year, shall consist of one member of the Society to be elected from and by each Section of the Society each year prior to the Annual Meeting of the Society, and three members of the Society who shall be appointed by the President within 30 days after he takes office. The President shall name the Chairman of the Committee.

Mr. President, I move that the Constitution be changed as stated.

[The motion was then seconded.]

Discussion of Papers at the 1924 Annual Meeting

THE discussion of the papers presented at the Motorbus Session and one of those presented at the Passenger-Car Session of the 1924 Annual Meeting included written contributions submitted by members and the remarks made at the meeting. In every case an effort has been made to have the authors of the several papers reply to the discussion, both oral and written, and these comments, where received, are included in the discussion. For the convenience of the members, a brief abstract of each paper precedes the discussion, with a reference to the issue of THE JOURNAL in which the paper appeared, so that members who desire to refer to the complete text as originally printed and the illustrations that appeared in connection therewith can do so with a minimum of effort.

It is expected that the discussion of the other papers presented at the Passenger-Car Session and those at the Research Session will be printed in full in an early issue.

THE FIELD AND FUTURE OF THE MOTORBUS

BY J. A. EMERY

[C 54 The Society shall not be responsible for statements or opinions advanced in papers or in discussions at its meetings]

MOTORBUS development in territory not served by railroads and as a substitute for or a supplement to railroads in other sections, is discussed. As the number of miles of surfaced highways in the United States at the present time is nearly 50 per cent greater than the total mileage of the railroad lines and about 2,500,000 miles of unsurfaced highways are available, the motorbus has open to it an enormous non-competitive field. Among the advantages of the bus are the low investment required and flexibility of operation. It is shown, on the other hand, that due to changes in conditions since 1910, to invite the construction of railroad lines, about four times the anticipated gross revenue is now required and about 2½ times as much traffic is necessary to produce the same operating revenue as was the case at that time. Electric railways demand a density of population of 1500 per mile of track for profitable operation, whereas one-sixth this amount is ample for motorbuses running on an hourly schedule.

As an adjunct to railroads the principal function of the bus is as a feeder in widening the available tributary territory. While the outskirts of a city are building up, transportation must be provided, and this can be offered better by the bus than by the railway because of the high cost of street-railway construction. Twelve hundred buses, more than one-half of which were ordered in 1923, are said to be in operation in connection with 121 of the 820 electric railways in the United States. Owing to the changing conditions, many electric railway lines have become unprofitable; on these the bus could be substituted to advantage, at least when replacements become necessary. The operating expenses of the bus and of the electric car are about equal, but the amount necessary for return on investment is from three to six times greater, dependent upon the density of traffic.

The usefulness of the railroad has been increased tenfold within the last 100 years by the invention of the telegraph, the Bessemer-steel rail and the airbrake; the efficiency of electric railway operation has likewise improved very greatly as exemplified by the progressive changes in powerplant apparatus and practice. In view of the rapid development in the efficiency of automotive vehicles within the last 10 years, it is probable that the progress of the bus industry will surpass that of steam and electric railways. Efforts must be directed toward producing comfortable vehicles with the maximum carrying-capacity, keeping the maintenance costs within bounds, operating economically and rendering reliable service. Body design seems to offer the greatest opportunity for improvement. The industry must profit by the experience of street railways and not extend fare zones to the point at which future profits will be compromised, and at the same time it must keep in mind the fact that high fares cut down the riding habit. As streets become more congested, it is probable that the use of buses will be encouraged over that of private cars because of the bus' greater carrying-capacity. [Printed in the February, 1924, issue of THE JOURNAL.]

THE DISCUSSION

F. C. HORNER:—Referring to the mass transportation of passengers, what is Mr. Emery's opinion regarding the zone-fare system in vogue in European countries, particularly England? Would it be practicable to use the zone fare in this Country on either buses or trolley-cars?

J. A. EMERY:—My opinion is that it would not be practicable precisely as operated abroad, but I have always believed that an adaptation of it would be possible in this Country. In that opinion I am in a very weak minority; that is, 9 out of 10 electric-railway men that I have talked with disagree with me entirely. They cite particularly the attempts that have been made in this Country to install the zone fare in Northern New Jersey, but I do not feel that these are conclusive. I have had in mind several practicable methods of doing it but, unfortunately, I have never been able to put any of them into effect. It is so desirable, though, that I believe it is bound to come.

MR. HORNER:—Will not the solution of handling mass transportation of passengers eventually lead to the underground subway for the long haul and the properly designed motorbus for the short haul?

MR. EMERY:—I think so, in cities of over 500,000 population. But it must be borne in mind that subway construction is enormously expensive; it is not practicable to install it anywhere and to any extent and make the traffic bear the expense; that is, the cities would have to bear a part of the expense in return for obtaining relief on the surface.

A MEMBER:—Everett, Wash., has been mentioned as one of the two cities in the United States where the

motorbus has successfully supplanted the street-car. The motorbus is also asserted to be one of the principal factors contributing to the development of the railroad. It may be interesting to know that all the motorbuses used in Everett are equipped with airbrakes; instead of the usual fabric-lined brake, they use a braking surface of metal against metal.

H. W. ALDEN:—I should like to give a few figures on on the question of transportation. It is very interesting to see the attitude of the electric-railway people and the way they hang on to the last ditch. We have now reached the point where motorbuses are ready for everything except mass transportation. In Detroit we have made some diagrams, with this result: That if you were to line up street-cars in a block, end to end, solid, and were to line up double-deck buses, such as we are using in Detroit, like the Fifth Avenue coach, end to end, along the curb, the buses would seat more than twice as many people in that length of a block as the trolley-cars would seat, and they would seat, I think, 10 or 15 per cent more than the trolley-cars could carry if loaded to capacity, both seated and jammed in, in the usual necessary way. This was very illuminating with regard to the seating-capacity per block of headway. In addition, you must take into consideration the flexibility of the motorbus which, as soon as it is loaded, pulls out and goes up the road and does not have to stop behind some street-car that may be half-loaded and is letting off or taking on passengers.

I think that unquestionably more passengers can be handled in the center of a district and some distance out by more buses, properly designed and handled, than by trolley-cars. We are also considering now, in Detroit, the possibility of making Woodward Avenue still more of a through-street than it is today, possibly stopping parking all the way up Woodward Avenue, and making only every second or third street a crossing street. If you wished to cross Woodward Avenue you could only cross at perhaps every third street, so as to give free run to the north-bound and the south-bound traffic at certain hours of the day. I should not be surprised, if we had buses enough, if we could handle the traffic on probably a 50-per cent better basis than the street-cars can possibly handle it today.

MR. HORNER:—It is rather significant to analyze some of the figures on transportation in this Country and in foreign countries with special reference to the motorbus. I believe the figures show that 50,000 motorbuses are operated in this Country, handling about 1,000,000,000 passengers per year. The London General Omnibus Co., with about 3500 motorbuses, is handling about 1,000,000,000 passengers per year in the metropolitan district of the City of London. Of course, many things that enter into the question here do not enter over there. For instance, due to the incentive of a short ride for a penny or two, a tremendous volume of short-ride traffic is handled under the zone-fare system that is in vogue on both motorbuses and tram cars in London, and in fact all over the British Isles. Nevertheless, the comparison is an interesting one to make; with approximately 50,000 motorbuses of all kinds here, including converted trucks, touring cars or anything that might be called a motorbus, we handle about 1,000,000,000 passengers. That is mass transportation, of course, considering numbers only; but in the correct sense of the term, our only bus systems dealing with mass movements are found at New York City, Chicago, Detroit and probably one or two other places.

CHAIRMAN A. F. MASURY:—One of the points Mr. Emery brought out was the question of service. How should it be handled?

A. J. SCAIFE:—I am not prepared to talk from a service standpoint, because we all realize that the industry is entirely new. The motor-coach industry is only 2 or 3 years old. We have been operating in cities which are under the control of companies that are used to mass transportation and, as the speaker well stated, have been organized to operate first the horse-car, and then the electric-car. At the present time they are taking over the motor-coaches, but, from an organization standpoint, they are not yet prepared to operate them so efficiently as they undoubtedly will be within the next few years. If the operating end of the motorbus has fallen down, it is due primarily to lack of organization and to the caliber of the equipment.

A thing that impressed me was the type of equipment in operation in Newark, N. J., a few years ago. It was just a lot of "cats and dogs" of all types. Many of them were up in the air, with the rear axle mounted under the center of the body like an old-fashioned teeter-totter; they had high wheels, and no two vehicles were of the same description; no two looked alike; they were just a miscellaneous mess. Naturally, it would be impossible for anyone to make money out of a proposition of that kind, or to maintain any kind of reliable service.

Last night, the motorbus I was on, going down Cass Avenue, Detroit, was full. The coach following us did not have many passengers and, at a point about where the automobile show is located, passed us. It simply reversed the conditions and picked up the passengers from that point on. That condition cannot exist on a street railway. I have in mind a similar condition in Cleveland. I was waiting for a car on a crosstown line; the street-car that I had come down on was crowded, yet stopped at nearly every crossing. That car was jammed, but behind it were four cars with trailers that were only half-filled. The first motorman was off his schedule, but made all the stops; it was impossible for the cars behind him to give any service at all. If the cars had been motorbuses the motormen behind could have pulled out of line and picked up the passengers ahead, thereby increasing the traffic facilities wonderfully.

Another thing that interests me is the street-railway situation in a comparatively congested district. Not only do the street-cars hold up the traffic but, in turn, the traffic holds up the street-cars. Cleveland is one of the worst traffic-congested cities in the Country; at certain hours of the morning, during the day, and in the evening, you will see from 10 to 15 motor cars between any two street-cars; the street-cars cannot go and the automobiles cannot go. How different it would be if motorbuses were operating along the curb. We have that condition in New York City. We can see how it operates there. I do not believe you will have to stretch your imagination much to think what would happen if street-cars were put on Fifth Avenue. I believe it would cut the traffic facilities in half.

R. A. HAUER:—We drive a great many trucks from our factory at Allentown, Pa., through Newark, N. J., to the New York City metropolitan district. During the street-car strike in Newark, our trucks were able to get through Newark in 25 min. less time than when the street-cars were operating.

MR. HORNER:—I made some observations in Newark, N. J., last summer when the trolleys had stopped running, on Market Street particularly, where the congestion is usually very bad. I noticed that the traffic was moving much faster because no trolley-cars were running and the

car-track space on the street was given over entirely to vehicular traffic. Even so, that space allotted to the trolley-car tracks was not nearly filled with vehicles, but it seemed to me that the traffic was moving 50 per cent faster than it would ordinarily go with trolley-cars on the streets, because the space that the trolley-cars would have occupied had been made available for vehicular traffic. Moreover, when a trolley-car stops, vehicular traffic behind it must also stop or at least slow up even where the streets are very wide. If the streets are narrow, every time a car stops the retarding effect on vehicular-traffic movement is felt for several blocks back, and when the traffic picks up speed and the cars stop again, the same thing happens with the result that in many localities serious traffic-congestion is unavoidable. It showed very clearly that street traffic-congestion would be greatly relieved by taking some trolley lines off the streets, although it might not be practicable to do this in every case where street congestion exists.

MR. HAUER:—About 10 years ago, a London commission, made an investigation of traffic conditions in that city, with a view toward widening the streets. It decided that if the speed of traffic could be increased 5 m.p.h. it would be equivalent to doubling the width of a street.

A MEMBER:—Does Mr. Emery think that pressure will be brought to bear or emphasis will be laid on making the motorbus more comfortable to ride in; that is, have more head-room and more space between the seats? Does he think a demand will be made for better lighting at night and better ventilation?

MR. EMERY:—I am of the opinion that the motorbus should be made as attractive as it possibly can be made. The motor car used for transportation is like that for merchandising; if you saw a department-store merchant who kept his front windows dirty, who piled boxes in front of the doors so that ladies had to jump over them to get into the store, who had clerks who were surly and inattentive, you would not think he was getting the most out of his business. The business of transporting traffic is one of sales resistance as much as any other business and the better you make the service, the more traffic you will get.

M. C. HORINE:—One point that I think has not been stressed much is that of safety. We have discussed how the motorbus will carry more traffic than can be handled on the street-cars. I think there is no question on that point; one has only to look at Fifth Avenue, as Mr. Scaife has suggested. To have a street-car operate on Fifth Avenue would be absolutely impossible.

When street-cars were originally put into operation, they were placed in the middle of the street in order that private carriages might park along the curb, and they have usually been placed there ever since. That necessitates passengers' walking to the middle of the street to board the car and getting off in the middle of the street on alighting. In the days of horse transportation that was perhaps safe enough, because horse-drawn vehicles moved at slow speed, and horses seemed to have a little more intelligence about running over persons than have some taxi drivers.

Today the danger is real. The safety isle has been invented; I think Detroit was one of the first cities to use the safety isle for street-car stops. That has been of some relief, but only at the cost of very greatly reducing the traffic capacity of the street, for traffic is not essentially flexible. Consequently, if you insert a bottle-neck, such as a safety isle, at fairly frequent intervals, you will slow down the speed of the entire traffic. It is altogether possible that with the increase in traffic congestion and traffic speed, the practicability of discharging and taking on passengers in the middle of the street may of itself be a great deterrent to further street-car operation.

CHAIRMAN MASURY:—Mr. Emery stressed the point of having service-stations, and the service that could be obtained by persons who bought buses. He talked about this being a virile new enterprising part of the automobile business; and it certainly is. It has attracted many persons into the manufacturing of buses and heavy commercial vehicles, and one of the things that I do not think it is fair for us to impose upon the operating interests is the carrying of enormous service charges, parts, engines and things of that sort. The companies in the heavy-engine business have a large number of places and have invested millions of dollars. Mr. Scaife's company has 47 large stations where it keeps parts; I believe its inventories would amount to at least $5,000,000 or $6,000,000. The company that I represent has a few more stations and about the same inventories.

With this vast amount of material distributed about the Country in every-day use, the motorbus industry can show operators of buses an enormous saving in running the vehicles over that obtained by going to new people who are attracted by the high rates at the present time.

MR. SCAIFE:—It is the hope of the motor-coach makers that the persons who are now handling mass transportation will "see the light." It will be much better for the companies that are operating now and have been operating mass transportation to handle the motor-coach business than to have it in the hands of many individual owners. Of course, cases will be found, especially in the suburbs, where individual owners will continue to operate for a long time, but in the large centers the business really belongs to those who have been and are now organized for mass transportation. They undoubtedly will maintain their own shops and will cut the operating costs to the minimum. But it will take some time to get the organization and the personnel, because the shop equipment and shop management will be entirely different from anything they have at the present time.

CHAIRMAN MASURY:—Committees appointed by the Society and by the street-railway interests have been holding joint meetings, at which an attempt has been made to agree on motor-coach sizes, weights, body dimensions, seats, nomenclature and so on. When we talk about de luxe bodies, it means something to us that is rather difficult to describe.

Two or three different kinds of service, perhaps the 5-cent and the 25-cent service, have been mentioned. Some persons would rather ride in an attractive coach than in their sedans; a decided endeavor has been made, both on the part of this Society and on the part of other interests, to get manufacturers to follow the standard thus set up, to have an amicable arrangement so that they will not be stepping on one another's toes on account of misunderstandings.

R. E. PLIMPTON:—It seems to me that we, as engineers, should be interested in supplying small operators with vehicles. Most of the discussion here has been on large city operation. As a matter of fact, I suppose one-half or three-quarters of the people of this Country live in rural districts or in small towns where not much local bus service is operated and what is operated consists mainly of carrying passengers to and from the nearest good-sized trading center. For that reason, I was interested in what Mr. Emery said regarding transportation with 1-hr. headway in sections where only 250

persons live along each mile of the route, or with 2-hr. headway where only 125 persons reside per mile of the route. I was interested particularly because recently I have made a study of school transportation. I think that economically it is a common-carrier proposition; that as these buses get into the rural districts where the population is small, they will take over that work. The schools now are trying to do it themselves, but I think, in general, that they are not doing it very well. They get high-school pupils to drive, and buy cheap second-hand equipment. We often hear of a so-called bus being hit by a railroad train, causing great loss of life, and find that it is a horse-drawn vehicle or a second-hand, rebuilt touring-car, used solely for school service. This is poor economy for the community and most unfair to motor common-carriers.

There are many motorbus operators in the country districts and, as the highways become improved and these common-carriers increase in number, I think they will get more and more into the school field. I ask Mr. Emery to go into that 125 and 250 residents per mile factor a little more, to tell us how long a run he is considering, what the size of the vehicle is and about what the vehicles cost.

MR. EMERY:—The figure that I used was, of course, rather rough and, as I stated, could not be taken as applying to all conditions. But the economics are briefly these: In an average district, such as we find between cities and through small villages, we can count on revenue of approximately $12 per capita per year. With a population of 250 per mile, that would make an average revenue of $3,000 per year per mile. The bus could readily make 12 m.p.h. under such conditions, probably more, but I think 12 m.p.h. is a reasonable figure, so that one bus could provide service over a line 6 miles long. To provide hourly service, approximately 10,000 bus-miles per year per mile would be required, or 60,000 bus-miles over the entire route. The revenue from 250 persons for the entire distance would be $18,000, or approximately 30 cents per bus-mile, which I think is a safe figure to cover all cost of service.

B. V. EVANS:—Reverting again to the question of traffic congestion, it is a fact that privately owned vehicles are increasing at a very rapid rate; the problem of congestion is one that we are already facing, but we shall have to face it more seriously in the future. One way in which we can increase the street capacity is by speeding-up traffic. If the street-cars were removed from the streets, thereby increasing the street capacity by approximately 30 per cent, the speed of vehicles and buses would be materially increased, and this, I think, would offer a solution of the problem of rapid transit in rapidly growing cities.

B. J. LEMON:—One point that has not been brought up regarding the future of the motorbus is that we must watch State legislation. The State of Oregon will allow a 17 or 18-passenger motorbus, with single 8-in. tires in the rear and single 6-in. tires in front, to operate at 30 m.p.h. The same motorbus with double 6-in. tires in the rear can operate at 20 m.p.h., that is, it is allowed a certain overall maximum tire width, counting all four tires. With 6-in. tires, we have 36-in. width, that is, single 6-in. tires in front and double 6-in. tires in the rear. The law says that any motorbus that has a total tire width of 28 in. or less can operate at 30 m.p.h.; anything over that, at 20 m.p.h.

CHAIRMAN MASURY:—Without question the laws must be revised to let this industry grow. I should like to emphasize one point that Mr. Emery pointed out, which is that the small motorbus operator can operate economically on a very small rate per passenger-mile. It is important to look into this business in this Country. After all these years, in New York City nearly 300 vehicles are operating. After several years, in Detroit 163 vehicles are operating. In Newark, N. J., the company I represent sold 402 buses last year, almost as many as operate in New York City and Detroit together; and Mr. Scaife's Company sold more than we did. So this business is vastly larger than that of some of the large operators.

J. C. HANDY:—The motorbus proposition, as viewed in the East, is somewhat different from the motorbus proposition as we view it on the Pacific coast. We have no towns on the Pacific coast that will support motorbuses on the public streets as New York City, Chicago and other municipalities do, but we have a large number of motorbuses traveling up and down the Coast from Canada to Mexico. We have motorbuses there that maintain traveling schedules that are comparable with railroad schedules. The roads are such that long-distance hauls can be made and, from what I understand, the companies that are operating over those long-distance hauls are making a financial success of it.

One problem which we have on the Coast, that does not bother you to the same degree, I think, is the deterioration of engines as a result of improper or inadequate lubrication. The runs are so long, and the duty imposed on the engines is so severe, that operators do not feel, as they should, the necessity for correct lubrication of the engines at all times. The company with which I am associated has spent considerable money, time and energy in educating the public to the idea of changing the oil in the crankcase as frequently as the manufacturers recommend; but it is a messy job, to say the least, and most people are probably inclined to let well enough alone, so long as their buses run and they can carry passengers and make a little profit. But it is costing them money to do it, in the replacement of parts that should, as a matter of fact, not be replaced until they have given much longer service than they actually do give.

We investigated this matter extensively and checked up the actual costs of repairs and replacements on our equipment on two bases: one, in which the oil was changed as frequently as it should be; the other, in which the oil was not changed so frequently as it should be. We have cut down operating and labor costs, so far as repairs are concerned, probably 35 per cent, by religiously following the recommendations of the manufacturers of the equipment.

But in going out among the people and investigating the whys and wherefores of changing the oils in crankcases and whether the recommendations of the manufacturers were followed, we found that in a great many cases they were not followed, the reasons being that, in the first place, it is a messy job and, in the second place, it is very inconvenient; and I dare say that in a measure they are right. I carry a scar over my eye that I got about 6 months ago in taking a drain-plug out of a car to change the oil. We developed a system of draining cars by vacuum, and are now placing that system in all our stations, of which we have approximately 1100 up and down the Coast. In other words, instead of forcing a man to climb under a car with a bucket or receptacle of some kind, and using a wrench to take the drain-plug out or, in some cases, kicking the receptacle under the car and opening a cock from the top, which is not so bad but nevertheless both are fairly inconvenient, we de-

veloped a system, or rather a device, so that the plug can be taken out of a motor car or a motor truck and one of our plugs, of the same size thread as the plug that originally came with the car, is put back in, but it is drilled and tapped to receive a connection with a copper pipe that runs up underneath the hood where it is secured; and it has a cap.

The result is that when the driver of a motorbus, motor truck, or a passenger-car drives into a service-station and says that he wants the oil changed, the boy raises the hood, takes a hose like an air-hose and puts it on the little copper pipe under the hood. If the car holds 11 qt. oil it will be drained in 55 to 57 sec.; if a Ford truck is being drained, it will take about 17 to 20 sec. When you take off the connection, the car has been drained. Not a drop of oil remains around it; it is clean, the job is well done, and you have not had to get out of your seat to do it.

The best feature of the device is that as the oil comes from the crankcase it goes into a 3-gal. bottle graduated into quarts. You can sit in the car, look at the bottle, see the condition of the oil and how much was in the crankcase. If you wish, you can take a sample of it, feel it or do whatever you like with it. We hope a similar custom will be followed all through the Country, so that a motorist will be able to drive up and have the crankcase drained without undue effort on his part. We are furnishing this device to motorists gratis.

Although we have a vacuum-pump in our stations to handle it, we have developed a steam injector, costing about $7 and procurable at any steam-supply house, that the garageman can buy and hook-up on his air-tank line. In other words, every garage has an air-pump and a tank for pumping-up tires; you can use this injector to syphon the oil out of the crankcase as well as you could if you were to go to the expense of buying a regular vacuum-pump. We have found that motorists will drain the crankcases as frequently as they should if facilities are provided so that they will not have to go to too much trouble and the work is not too dirty.

CORNELIUS T. MYERS:—Referring to the California idea of having stations equipped for draining diluted oil from the crankcase, we found that we could very readily use this thin and dirty oil in the magazines of our chassis-lubricating system. In summer, the thin oil has a tendency to feed fast, but it can be checked by a little splinter of wood put into the hole that holds the wick. The oil can be dirty and not affect the operation of the devices, because the dirt does not get past the wick. The magazines can readily be made to hold from 3 to 6-months' supply of oil, in which case they are filled in the spring and summer with the oil that is ordinarily put into the engine; and in the fall and winter they are filled with the thinner oil that is drained from the engine. These schedules have been successfully maintained over a period of years.

THE DOUBLE-DECK MOTOR OMNIBUS

BY RICHARD W. MEADE

DOUBLE-DECK horse-drawn buses did not meet with much favor in the United States, but from the earliest days have been popular with persons of all classes in England, probably due in part to the British nation's love of outdoors and in part to the governmental policy of prohibiting the carrying of passengers in excess of the seating-capacity. Packed vehicles continued to be characteristic of transportation in this Country until public service regulation in the early days of the present century required that a reasonable number of seats should be provided. When the number of passengers was limited to the number of seats, at the time of the introduction of motorbuses on Fifth Avenue in New York City, the failure of the experiment was predicted, whereas subsequent service has proved it to be the cornerstone of success. London double-deck buses with 78 seats require about 3 sq. ft. of street space per passenger, while the latest type with 50 seats require about 4 sq. ft. In this Country with the increase in size of the bus the street space per passenger has been reduced from 5 to 3 sq. ft. Private passenger-cars require from 14 to 112 sq. ft. The criticism of slowness of operation that has been urged against the double-deck bus may be largely neutralized by keeping the aisles free and promoting quick loading and unloading. Enclosed upper decks cannot be used in some cities on account of the low vertical headroom due to the presence of overhead railroad viaducts and the like.

Competition in London for the business of the 15,000 cabs and 3700 buses that were in use at the height of the era of horse-drawn vehicles produced a revolution during the years from 1905 to 1908. The result was a merger of the three larger companies and the adoption of a standard chassis embodying the best points of the 28 different types previously used, special attention being devoted to the reduction of weight and noise. As the London police regulations required each vehicle to be presented annually for relicensing, the London General Omnibus Co. instituted the practice of completely rebuilding each of its vehicles during the winter. One of the benefits that resulted was the designing of the various units and the methods of mounting them so that the time of making adjustments and of replacing one unit with another was minimized. Increased operating costs during the war brought concessions from the police authorities regarding carrying-capacity and a type of bus was produced approximating that of the Fifth Avenue Coach Co.'s type L. Development on the Continent did not keep pace with that in England and the United States, the double-deck buses in Paris being replaced by the single deck, while the service in Berlin contained only about 200 double-deck omnibuses.

In 1904 the Fifth Avenue Coach Co. owned about 60 horse-drawn and 13 electric storage-battery omnibuses and was operating at a deficit, only six of the buses having sufficient seating-capacity to operate at a profit. Only 4 miles of streets was used in regular operation and the fare was fixed at 5 cents.

After experimenting with a gasoline-electric system for 2 years, in 1906 a De Dion Bouton chassis equipped with a standard London double-deck type of body was tried and, having been found satisfactory, 14 more chassis were ordered and the bodies were built in this Country to fit them. This same type continued to survive in London after 29 other makes had disappeared. Among its advantages were lightness, minimum unsprung weight, forced-feed lubrication, low consumption of fuel, single-disc clutch and general excellence of material and workmanship. Its disadvantages were automatic poppet valves and no direct drive on high gear.

In 1908, with the extension of the service over

Riverside Drive, a bus having double the capacity of those previously in service was tried and 25 additional ones of this type were then ordered. In them modifications of London practice were introduced, including drop windows, a storage-battery for lighting, folding doors, electric signal-bells, push buttons, a heating system supplied from the engine exhaust, illuminated roller-curtain signs, double hand-rails for safety and a windshield for the driver. Horizontal tubular-type radiators were substituted for the honeycomb type. Further simplification was made later by the use of semi-floating axles, steel wheels and standardized steel-base tires and by improving the quality of the tires. About 1910, Moline Knight sleeve-valve engines were first tried and have proved very successful.

Refinements that have recently been added to meet the requirements of other cities in which bus service has been introduced include the reduction of the height to enable buses to pass under low viaducts, the increasing of the capacity to 67 passengers, rubber shock-absorbers instead of spring-shackles, a generator for lighting that makes it unnecessary to carry a large battery for this purpose and a regulator that prevents overcharging. In the effort to avoid complications the use of the fixed spark has been considered as indispensable. An important improvement that remains to be developed is the enclosed upper deck with a covering of the nature of a one-man top. When this has been produced it will give the bus an all-weather all-season capacity that will put it in its rightful place in the scheme of transportation.

Among the factors that are suggested for guiding the future design of the bus are safety, maximum comfort and convenience of the passenger consistent with a reasonable occupation of street space, minimum operating cost and maximum safe speed. Steam, generated by low-grade fuel, is predicted as the future motive power. [Printed in the February, 1924, issue of THE JOURNAL.]

THE DISCUSSION

V. E. KEENAN:—Mr. Meade has given you an historical sketch that in future years should make an ideal prelude to a story of what we believe will become a thriving national industry. He has told you how, in a relatively short period of years, the riding public, by its patronage at a higher rate of fare, has indicated its desire to be transported by motor-coaches, wherever motor-coach operation has been intelligently directed. The steam-railroad and the electric-railway industries are found wanting in an effort to discover a similarly romantic development.

Mr. Emery and the firm with which he is connected have rendered an immeasurable service to the steam railroads and the electric railways of this Country for a number of years, by crystallizing a variety of schemes into practices, which in actual service have proved profitable to the railways that have availed themselves of them. We have heard from Mr. Emery what surely must be regarded by the electric-railway industry as a prophecy that will become apparent within the next few years.

The transportation company that I represent has realized for some time the inherent possibilities and the advantages to itself as a unit that motorbus operation would have; consequently, the United Electric Railways Co. in Providence, R. I., embarked in a modest scheme of motorbus operation on July 3, 1922, rendering a service that Mr. Emery describes in his paper under classifications (4) and (5), namely, a differential service, and on special routes where the railroad lines were not convenient.

Although these operations met with more or less success, their value as a whole to the company could not be indicated by figures on the balance sheet. On May 20, 1923, we began operating a motor-coach route that might properly be described by referring to Mr. Emery's classification (1), namely, that of a combination express and local service rendered by electric-car and motor-coach. This form of operation is really unique and, so far as we have been able to determine, is the first of its kind in the Country, surely the first in the East.

The success of this operation has been so pronounced that a brief description of the manner in which it is being conducted may prove beneficial to automotive engineers, as in all probability they will occasionally be called upon for views as to the proper application of motor-coach equipment.

The route in question is over a wide well-paved street, reasonably free from intersecting streets having heavy traffic, and forms the main artery for all motor and mass traffic between the business center of Providence and a suburban business center known as Olneyville. Olneyville is a converging point for several suburban electric-car routes. City-bound from this point, all the electric-car operation is over the business district referred to above.

For some time a decided public demand has been made that more rapid transportation be provided for residents of the suburban section beyond the Olneyville district. A very capable consulting engineer, in a report submitted some time prior to this date, recommended the installation of passing tracks on Broadway, to allow the rapid movement of electric cars in both directions between Olneyville and the business district of Providence, passing local electric cars en route. Slowly the motor-coach began to appear as a more economical means of achieving this result. It was possible to purchase sufficient equipment to handle adequately all the local traffic between these two points for practically the same capital investment that would be required to install the recommended passing tracks and overhead equipment. The purchase of motor-coaches had the added advantage of allowing us to transfer the equipment to other routes, if the experiment proved unsatisfactory.

This operation of a combined express service with electric cars and a local service with motor-coaches has been economically successful from the beginning. Some public opposition arose at first that was completely removed later by moving the in-bound terminus some 300 ft. from its original position. At the present time, local passengers that formerly crowded aboard electric cars already filled with patrons of the suburban district are offered a seat in a motor-coach, while the suburban residents are finding satisfaction in the more rapid movement of electric cars between the two business centers.

An annual saving amounting to $83,419.56 has been produced through eliminating car-hours and car-mileage, formerly necessary in the handling of local traffic on this route. Chargeable against this figure, of course, must be the annual operating expense of motor-coaches, which amounts to $62,025. We have thereby effected an annual net gain of $21,394.56; that is beneficial, of course, to the railway-operating expense, yet does not appear as a credit on the balance sheet for motor-coach operation. During 224 days of 1923, our motor-coaches carried nearly 1,000,000 passengers over this route alone, the exact figures being 995,848, and ran during peak hours on a 2½-min. headway between coaches without injury to a single passenger during this period.

The unique features of this operation, comprising the resulting satisfaction to both the long-distance electric-car riders and the local patrons who now have the assurance of a seat, coupled with the more frequent service

by motor-coach, have opened up a new field in the scheme of coordinated service; and this today is directly in line with the policy of all progressive street-railways.

This brief description concerns only one of Mr. Emery's classifications of methods in which the motor-coach is valuable as an adjunct to the electric railway. Our management feels with him that the motorbus is here to stay, and that, wherever the proper type is properly applied and properly supervised, success to the operating organization will be forthcoming.

We, in the electric-railway group, feel that automotive engineers have an immense task ahead of them before the railways, as a whole, will recognize the motorbus as an adjunct. An exceptional amount of thought and talk at the present time is being given to the superiority of certain units and to the relative merits of completely assembled chassis. But maintenance is the thing, and the engineer who designs motor-coach equipment without giving thought to standardization and with little apparent thought to the maintenance of the equipment 2, 3, 4 and 5 years after it has left the factory will do more harm to the industry than he has the vision to realize.

B. V. EVANS:—Every city presents different conditions, and, of course, changes have been made to meet the conditions as they presented themselves in Detroit, but the Detroit Motorbus Co., which was conceived and organized by Mr. Meade, has followed the fundamental principles of operation laid down by the Fifth Avenue Coach Co. and has had a notable success both in public favor and financially. Since its inception in 1920 it has operated 12,000,000 bus-miles and the eight original motorbuses have grown to 163 at this time. It was the first company to operate successfully a 60-passenger motorbus. Practically all the motorbuses are equipped with the semi-covered top on the upper deck.

Mr. Meade could probably recount many experiences with the early motorbuses that would sound very humorous in the light of present-day developments. I have heard some of the men who drove those original gasoline-electric buses reminisce about their operation. It seems that when the switch was thrown to start, it would not always make contact, so that it was necessary for the driver to get out and tinker. When the vehicle would start, the driver would have to catch it on the run and get back into his seat; and he was not always successful in catching it before it had been stopped by some obstruction. The motorbus has now reached a high stage of development. One of the best proofs of this is the fact that our vehicles run an average of 150 to 200 miles per day, in the most severe service, and continue to do so day after day. At the end of a year it is their appearance that demands attention rather than the mechanism.

I feel that the future will see no fundamental changes in design but only such refinements as will tend to reduce maintenance costs or will be required to keep pace with the public demand for comfort. One of the developments that we may expect in the near future is the use of a high-compression engine. A gasoline-distillation process has been invented by Dr. A. S. Rammage of Detroit, the product of which is capable of withstanding a compression of over 150 lb. per sq. in. without knock. When this is compared with the present compression of about 70 lb. per sq. in., its possibilities for economy are evident; and I understand it can be made cheaper than present-day gasoline.

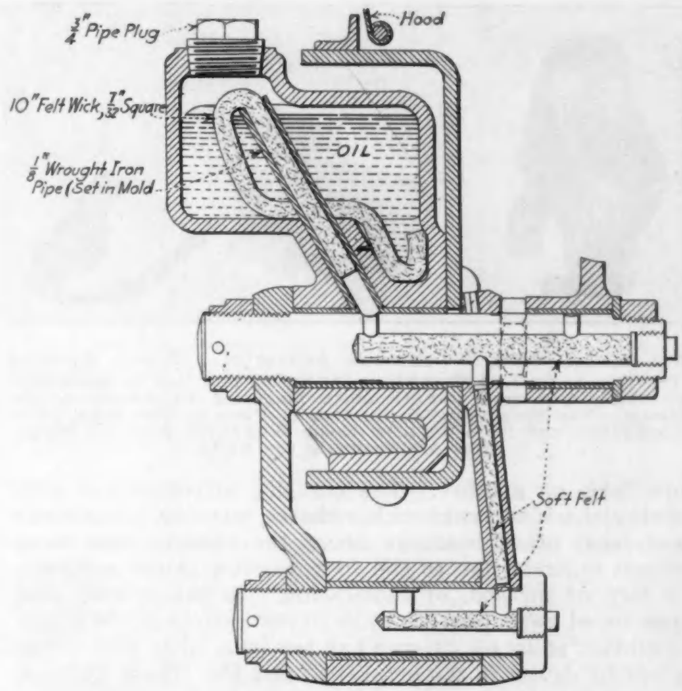

FIG. 1—MAGAZINE OILING SYSTEM FOR A FRONT SPRING-SHACKLE OF A PASSENGER CAR

This Is an Example of Adding a Magazine to Production Patterns and Feeding Both Spring-Bolts and a Brake Rocker-Shaft from It. Four Fillings per Year Is All That Is Necessary

I feel safe in saying that 67 passengers is practically the limit of the carrying-capacity of a double-deck motorbus from the standpoints of design, maintenance and operation; I say this because, in the first place, each additional cross-seat calls for an increase in the length of the vehicle of approximately 30 in. As the length of the present 67-passenger motorbus is 27 ft., it is apparent that any additional length of body and wheelbase will make the vehicle unwieldy. Additional length and capacity also mean additional weight which is attended by increased operating cost; also the schedule speed would be affected by increased capacity and this, as Mr. Meade has pointed out, is a factor that is vital to successful operation. To make a motorbus unwieldy and slow defeats its advantages, puts it back in a class with the surface car and lessens its ability to compete with the privately owned car that the public prefers because of its speed and in spite of its extravagance.

CORNELIUS T. MYERS[1]:—Mr. Meade and others have laid commendable stress upon a fundamentally important consideration in motorbus design, low maintenance charges. In this connection, he mentions the substitution of rubber blocks in place of spring-shackles.

The problems involved in motorbus spring-suspension are not of the simplest, and those affecting the details of spring-shackles and bolts have long been most troublesome, largely because these bolts have not been lubricated advantageously. In view of this, and of the use of rubber for spring connections in the obvious attempt to avoid the use of essential features of good design at these points, I should like to present the case of the Myers magazine oiling system, illustrated in Fig. 1, for solving these and other problems of chassis design. The record of this system shows that it has put the lubrication of the chassis in the same class with that of the transmission and the rear axle, almost foolproof operation with only occasional attention.

The life of all mechanism depends upon lubrication in

[1] Chassis Lubricating Co., Rahway, N. J.

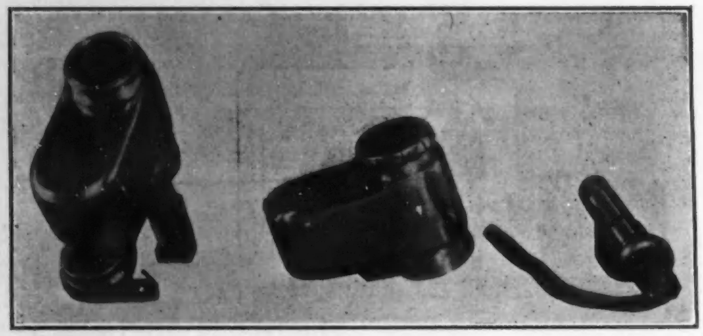

FIG. 2—THE STEEL MAGAZINE AS APPLIED TO A FORGED SHACKLE
The View at the Left Shows How the Spring Bolt Can Be Assembled or Withdrawn from the Complete Magazine Illustrated in the Center. The Snap Cap Can Be Seen in Place in This View. The Spring Bolt and the Wick after Being Withdrawn from the Magazine Are Shown at the Right

one form or another. The troubles in connection with spring-shackles, brake rocker-shafts, steering connections and most other bearings about the chassis have been almost entirely due to the inexpressibly crude methods, or lack of method, of lubrication. In the system just mentioned each bearing or adjacent group of bearings is lubricated by oil, filtered and fed by a large wick, from a nearby cavity in the bracket or shackle. These cavities, or "magazines," shown in Fig. 2, hold from 2 to 6 months' supply of light engine-oil, thus reducing attention to the insignificant figure of less than 3 hr. per year per bus. They supply a small but ever-present amount of ideal lubricant to each bearing as it needs it.

The system has been in use since 1916, when it was adopted by the Fageol Motors Co., of Oakland, Cal., makers of the Safety Coach. It has been applied to more than 25,000 motorbuses and motor trucks, by a dozen different manufacturers. In all this time no failures have been recorded; on the contrary, all reports bear testimony to the efficiency of the system. Records show that many of the vehicles have traveled upward of 150,000 miles, and that the spring-bolts, brake rocker-shafts, steering connections and other chassis bearings so lubricated showed so little wear that they did not need replacement when the chassis were overhauled; whereas the engines, and in some cases even the rear axles, had to be rebuilt before being put back into service.

A secondary but important advantage gained by the use of this system is the slight but constant lubrication afforded to the springs. This is effected by a small amount of seepage of oil from the ends of the spring-bolt bushings, which creeps along the spring leaves and slowly works between them. This keeps rust from forming and stiffening up the spring action. When rust forms between the leaves it often stretches the clips that hold the spring to the axle; and breakage near the spring-seat sometimes results. Breakage near the spring-eyes is almost always caused by binding at the spring-eye bushing, or by localized stresses that are set up when the leaves cannot work freely over one another in the manner intended. Reports state that not only is easier riding noticeable, but that spring breakage is almost unknown since the adoption of this system.

Early forms of the magazine system made it seem difficult of adoption, unless the frame brackets and shackles were redesigned to form the magazine cavities. Although this involved comparatively small expense, some reluctance on the part of manufacturers to make the change when other matters were absorbing their attention has been encountered. The importance of efficient chassis lubrication is now generally recognized and is in process of adoption.

For several years the company with which I am associated has been working on the development of this system in pressed steel and brass for application to the types of shackle and bracket now so largely in use. The newer magazines can be readily applied to the usual chassis construction. Snap caps that may be taken off and replaced instantly by thumb and finger pressure are an additional improvement. This system will afford indefinite life to properly designed chassis bearings, with an insignificant charge for attention; it makes an easier-riding vehicle; it eliminates squeaks and slaps; it reduces spring breakage; no innovation in spring design is required; and no perishable material is introduced between heavily stressed parts.

THE ESSENTIALS OF A SUCCESSFUL CONSTANT-COMPRESSION ENGINE

BY C. E. SARGENT

[C 54 The Society shall not be responsible for statements or opinions advanced in papers or in discussions at its meetings]

THE efficiency of internal-combustion engines increases with the pressure of the charge at the time of ignition. Therefore, a compression at full load just below that of premature ignition is ordinarily maintained. But when such an engine is controlled by throttling, the efficiency drops as the compression is reduced, and as automobile engines use less than one-quarter of their available power the greater part of the time, the fuel consumption is necessarily high for the horsepower output.

On account, also, of the rarefaction due to throttling, more power must be developed than is necessary to drive the car; automobile engines in which the fuel is introduced during the induction stroke, would be more efficient, therefore, if the maximum compression were constant during all ranges of load. In the design under consideration this feature is accomplished by allowing free air, or the products of combustion, when the engine is running at less than full load, to enter the cylinder first, and the gas charge last so that it will be adjacent to the spark-plugs at the ignition time. By designing the combustion-chamber so that it will maintain a stratified charge during compression, ignition is effective, irrespective of the number of heat units introduced or the mean effective pressure desired. In the gasoline fuel at present available the induced charge is composed mostly of air with liquid spheres floating in it, so that violent agitation during the heat of compression is necessary to convert the liquid particles into gas; but the time is so short that, even with the maximum amount of perturbation, a considerable part of the fuel content is unconsumed.

While turbulence seems necessary for ordinary variable-compression prime-movers, it would be fatal to a constant-compression engine the cycle of which depends upon stratification. To operate such an engine successfully, the fuel, before admission, must be converted into a fixed gas without raising the temperature of the air above the dew-point.

When accomplished in the manner shown, a constant-

compression engine is entirely feasible. It may be constructed with a distributing-valve that varies the time during which air and gas are admitted or with poppet-valves that control the intake gases in the same way. While such an engine should have practically the same efficiency at full load as engines of standard construction, the fuel consumption per car-mile on less than full load should be considerably less. [Printed in the January, 1924, issue of THE JOURNAL.]

THE DISCUSSION

H. A. HUEBOTTER:—Mr. Sargent's charge against the automotive type of internal-combustion engine is well founded. The ordinary throttle-controlled gasoline-engine is decidedly wasteful of fuel at loads below 50 per cent of its maximum capacity. In view of the fact that the average automobile engine is seldom required to exert its full torque, any design that tends to increase the economy at part load is of interest to the automotive engineer. This being the case, it may not be amiss to consider some of the factors in engine design that affect fuel economy and to show by experimental evidence how some of these factors act.

Mr. Sargent's premise is that economy is promoted by high compression-pressure at the time of ignition. This is true in a general way, but the method by which high compression is secured has an important bearing upon the results. The pressure of the charge at the end of the compression stroke depends upon two things, the pressure at the beginning of the compression stroke and the compression-ratio or the relative change in volume during the stroke. The question naturally arises as to the effect of these two factors upon the economy.

As a preliminary step in the analysis of the question, let us assume that combustion is complete at top dead-center. Under this condition we might reasonably expect to realize an indicated thermal efficiency approximating that of the ideal Otto cycle, were it not for the radiation losses. The mathematical equation for the ideal efficiency is $E = 1 - (1/R^{n-1})$ where R is the compression-ratio, which is equal to the expansion-ratio, and n is the ratio of the specific heats of the working fluid. The empirical value of n is usually given as 1.3, which is not far from the average gas constant at the working temperatures of the engine. The above equation simply states in quantitative terms that the more the gas is expanded in the cylinder after combustion, the greater is the proportion of its thermal energy that can be converted into work. It is worthy of note that this equation does not recognize the effect of compression pressure, but it is based upon the assumption of combustion at constant volume. Rapid combustion is assisted by high compression-pressure, proper fuel-air proportion, turbulence, and the absence of diluent gases in the charge.

To what extent the ideal thermal-efficiency is obtained in practice can be learned by laboratory investigation. In Fig. 3 are plotted the values of the indicated thermal-efficiency of an engine running at a constant speed on the same quality of fuel-air mixture. The engine had originally been built with a compression-ratio of 4.45, which gave a compression pressure of from 75 to 80 lb. per sq. in. gage. The compression-ratio was later raised to 6.75 and the compression pressure went to 120 lb. per sq. in. gage. Neither of the efficiency curves shows an alarming variation within the upper two-thirds of the indicated-horsepower range. It seems probable that, over this range, the change in the combustion rate due to the change in the compression pressure and in the proportion of inert gas from the preceding cycle was compensated for almost entirely by the variation of the spark-advance. The percentage of heat radiated to the water-jacket is, however, much greater at light loads than at heavy loads, which fact would account for the slight drop in efficiency. For example, at 14 i.hp., with the high-compression ratio, the jacket loss was 900 B.t.u. per min.; whereas, at 28 i.hp., it was 1250 B.t.u. per min., this being a 40-per cent increase in radiation for a 100-per cent increase in load. The compression pressure at the lightest load in the upper curve was about 50 lb. per sq. in. gage. The greatest variation in efficiency between 50 and 120 lb. per sq. in. gage from the full-load efficiency was less than 10 per cent of the latter value. The compression pressure at the point a on the upper curve was slightly less than that at point b on the lower curve. The greater expansion of the burned charge, however, increased the thermal efficiency 28 per cent at the same compression-pressure and from 20 to 30 per cent at the same loads. Unfortunately for the present discussion, the load on the high-compression engine was not carried below 25 per cent of the maximum brake-load. On the low-compression engine, the point c corresponds to 25 per cent brake-load, below which the efficiency drops rapidly. The effect of low compression-pressure is very pronounced at the light loads.

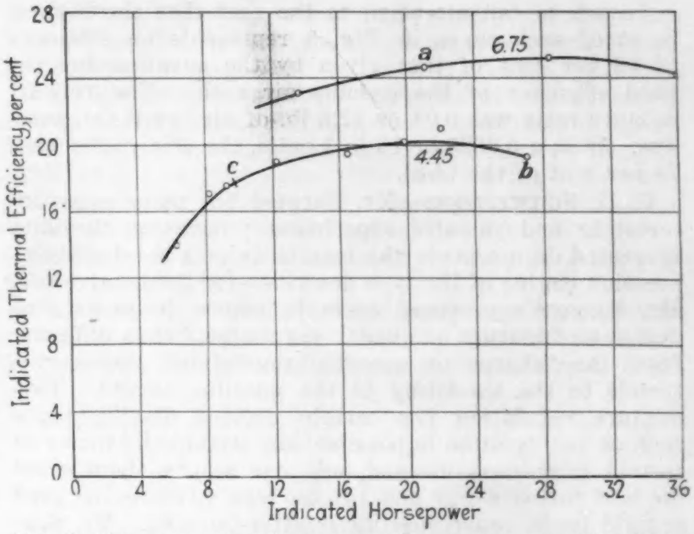

FIG. 3—EFFECT OF THE COMPRESSION-RATIO AND THE LOAD UPON THE THERMAL EFFICIENCY

The Curves Give the Values of the Indicated Thermal Efficiency of an Engine Running at a Constant Speed on the Same Quality of Air-Fuel Mixture. The Lower Curve Was Obtained at the Original Compression-Ratio of 4.45 to 1, Which Gave a Compression Pressure of from 75 to 80 Lb. per Sq. In. The Compression-Ratio Was Subsequently Raised to 6.75 to 1, Which Increased the Compression Pressure to 120 Lb. per Sq. In. The Upper Curve Was Obtained at This Ratio. Neither of the Curves Shows a Great Variation within the Upper Two-Thirds of the Indicated-Horsepower Range. Over This Range the Change in the Combustion Rate Due to the Change in the Compression Pressure and in the Proportion of the Inert Gas from the Preceding Cycle Was Probably Compensated for Almost Entirely by the Variation in the Spark-Advance. These Curves Illustrate Two Facts That Should Be Kept in Mind as Fundamental in Any Attempt To Improve the Economy of an Internal-Combustion Engine. They Are That (a) the Indicated Thermal Efficiency of an Engine Is a Function of Its Expansion-Ratio and (b) the Indicated Thermal Efficiency Is a Function of the Time Required for Combustion

The curves in Fig. 3 illustrate two facts very clearly. These facts should be kept in mind as fundamental in any attempt at improving the economy of an internal-combustion engine. They are that (a) the indicated thermal-efficiency of an engine is a function of its expansion-ratio and (b) the indicated efficiency is a function of the time required for combustion.

To obtain a high brake-thermal-efficiency, the friction losses in the engine must be reduced to a minimum. It is interesting to note that Mr. Sargent's engine eliminates the high pumping-loss of the throttled engine at light load.

I wish to call attention to the fact that the highest point of each curve in Fig. 3 represents an efficiency of 58 per cent of that given by the equation for the ideal efficiency of the gasoline-air cycle. The fuel-air mixture-ratio was 0.08 or 12.5 lb. of air per lb. of gasoline. With a 0.0625 or 16 to 1 ratio, the efficiencies were 70 per cent of the ideal.

C. H. SCHWEITZER:—Mr. Sargent has made some interesting and valuable experiments; however, the data presented do not prove the feasibility of a constant-compression engine of the type described for automotive use. Mr. Sargent's proposed cycle is known in gas-engine design as "mixture or quality regulation," thus differing from the "charge or quantity regulation" that corresponds to the throttling of the gasoline engine. This mixture regulation has certain decided disadvantages such as (*a*) ignition is possible only within the limits of certain mixture-ratios and only one among them gives the best fuel-economy and (*b*) too lean mixtures, as used at light loads, cause missing or after-burning. Mr. Sargent tried to eliminate this disadvantage by a stratification of the charge, to get a quick ignition in the rich mixture adjacent to the spark-plug. To reach this result, he partly eliminates the turbulence in the cylinder and replaces it by an outside turbulence produced by fans. He says, "as only pure gas reaches the combustion-chamber, violent perturbation or turbulence is superfluous."

This is a mistake. Mr. Sargent has misunderstood the part that turbulence plays in the combustion. The most important effect of the turbulence is the speeding-up of the combustion. I recall the striking experiments of Dugald Clerk with a *gas engine*. He ran the engine under normal conditions and obtained a regular diagram; then he shut off the ignition and, a little later, the intake and the exhaust-valve were shut. In this way, the turbulence in the cylinder was damped and then came to rest. When he turned on the ignition again, he obtained a much lower and an entirely undesirable diagram that showed considerable after-burning. Prof. G. B. Upton, in a paper entitled Spark-Advance in Internal-Combustion Engines,[2] concluded from Hopkinson's experiments that "turbulence cuts the explosion time in two at 1000 r.p.m., divides it by 3 at 2000 r.p.m., and so on. In racing engines the explosion times drop to 1/5, and in engines with small cylinders they drop perhaps to 1/10." Thus, the elimination of turbulence is a poor way to increase the economy and is probably inapplicable to high-speed engines. This is proved also by Mr. Sargent's indicator-diagrams. I have analyzed the second one in Fig. 9 of his paper, which looks the best, by the exponential method, and found considerable after-burning. Even in the case of an absence of turbulence, the stratification of the cylinder content would be incomplete. The spent gases at the beginning of the induction stroke have a higher pressure and temperature than has the mixture sucked in later. This accelerates the mixing and decreases the inflammability of the mixture, as shown also by Mr. Sargent's diagrams taken at part load with unchanged ignition-timing.

In the engine described, a decrease of turbulence is obtained by allowing a full-area air-passage, thus decreasing the air velocity. This has another undesirable effect. Successive mixtures for the same load conditions will not be of uniform composition at the ignition points. This will cause variable explosions, resulting in variable torque and fluctuating speed in multi-cylinder engines. This conclusion is borne out by the spreading diagrams obtained by Mr. Sargent. Another disadvantage in an automobile engine of the type described would be that it would have full compression at starting, making cranking more difficult. I would like to ask Mr. Sargent if the hot surface of the wall *h* is hot enough to vaporize all the fuel at light load and cool exhaust when there is no rarefaction to assist vaporization.

I agree with Mr. Sargent's opinion that "the ultimate solution of the problem will, no doubt, be an engine of the Diesel type." This will eliminate the justifiable criticism Mr. Sargent has made of the present type of automotive engine without adding most of the deficiencies mentioned.

C. E. SARGENT:—Dugald Clerk's experiments referred to, of cutting out the ignition and keeping all valves closed for several engine revolutions before firing the mixture, in which a lower mean effective pressure is obtained, do not prove that turbulence is necessary for a high thermal-efficiency. In fact, churning the mixture back and forth during several piston strokes ought to cause a better commingling of the confined gases. The cause of the lower mean effective pressure might have been leakage and loss of heat to the cylinder-walls.

As to the importance of turbulence in speeding-up combustion, a dry homogeneous mixture does not need turbulence; you cannot get out of the gas any more heat than there is in it, in spite of unlimited stirring. If the exhaust shows no carbon-monoxide content or no unburnt mixture, good combustion is attained.

Rapid inflammation, caused by turbulence, the gentleman claims, means high thermal-efficiency. It can be too rapid. If we burn hydrogen without retarding the ignition, we get an initial pressure that is five or six times the compression pressure, permitting the heat to be absorbed by the walls before the piston starts. Consequently, we get very poor thermal-efficiency when the inflammation is too quick. From experiments made 20 years ago, it was found that the highest thermal-efficiencies were obtained when the angle of inflammation was about 15 deg. past the vertical. With such timing the piston is moving as the volume increases, thereby preventing a loss of heat to the cylinder walls.

My experience as regards starting with constant compression has been that we get full compression in cranking a cold engine, no matter how much it may be throttled. Yet, with the throttle wide-open, a starter will crank the engine with full compression about as quickly as it will without it.

QUESTION:—Is the heat at idling loads sufficient to gasify the fuel when there is no rarefaction?

MR. SARGENT:—I presume that, ordinarily, rarefaction materially assists gasification if sufficient heat is not available, but with the device I described the liquid fuel, away from the air, is heated by the exhaust gases, so that rarefaction is superfluous.

QUESTION:—What is the total friction and pumping-loss at approximately one-quarter load on constant-compression engines as compared with that of throttling types under the same conditions?

MR. SARGENT:—I do not know. Experimenting in a machine shop is different from experimenting in a research laboratory. The only comparable result that I obtained was that on light loads the revolutions per unit of fuel with the constant-compression engine were 17 per cent more than with the same engine throttling, which is not enough to make much difference.

QUESTION:—Did you note any carbon due to the cracking of the fuel in the exhaust heating-chamber?

MR. SARGENT:—No. I have examined this exhaust

[2] See THE JOURNAL, August, 1923, p. 111.

heating-chamber after making a long tour, and have found a considerable quantity of the same kind of stuff that you find in the explosion-chamber, a sort of brown dust and dirt. I have never seen enough carbon accumulation to require cleaning or to insulate the fuel from the exhaust. Upon examining the fan, after driving on the road, I found that the front side was scoured and polished; and upon investigation it appeared that much of the dirt that went into the air was caught in the film of oil and delivered to the heating-chamber, in the same way as with the heavy fuel.

QUESTION:—Do the extra cam-gears present unusual difficulties in making quiet operation?

MR. SARGENT:—The engine was very noisy before it was changed over to constant compression and the change did not improve it. The camshaft presented a problem to its makers. They made two and shipped them before they found out exactly how to make them; and after they learned that the tapered cam was a warped surface and could easily be made with a milling cutter, they said they could make a camshaft nearly as cheaply as they could the ordinary typical camshaft.

QUESTION:—Is not the wear on the cams and the followers considerable, due to localized contact on the tapered cams?

MR. SARGENT:—I thought that it would be. The roller, of course, is crowned, so that it will follow the tapered cam and always travels on the center. After a long series of experimental runs, it was examined very carefully; the roller showed no evidence of wear. The theoretical line of contact was about 3/32 in. wide and highly polished, showing that its elasticity gave it considerable bearing.

QUESTION:—Is not a 17-per cent gain in fuel economy at light load much below that expected or possible?

MR. SARGENT:—I think it is. I gave that only because it was all the recorded evidence I had on the subject. I think we can get better results than that under the proper conditions.

QUESTION:—In the so-called "Dempsey cycle," air being admitted near the outer center of the piston through an automatic valve in the cylinder wall, what are the maximum pressures?

MR. SARGENT:—I do not know much about the Dempsey cycle or the efficiency attained. I believe that if the automatic valve is large enough, maximum compression in the cylinder would probably be obtained at all loads; but manifold rarefaction is one of the many disadvantages of an engine of that type. I do not know whether Mr. Dempsey has increased the efficiency.

As to the maximum compression, 90 lb. per sq. in. gage was the pressure carried. The indicator was not adapted to this kind of work.

QUESTION:—Does the fan device cause sluggish acceleration?

MR. SARGENT:—I do not know, but think not. I have driven many engines equipped with a fan device and never could notice any difference; I have never timed the acceleration, but I do not think it is appreciably sluggish. No throttling in the fan to speak of takes place. The fan diameter is twice the normal carbureter diameter. When a cold engine is started, the heavy fuel is thrown out by the fan, making such a lean mixture that the engine often backfires until the exhaust begins to vaporize the fuel as fast as the fan delivers it to the heated chamber. If the engine is running on a heavy load and stopped, the chamber will be as dry as a bone; but, running on a light load, you draw off a small quantity of liquid so heavy that it will put out a match.

QUESTION:—How slow would the engine idle and what was the number of revolutions per minute at maximum horsepower?

MR. SARGENT:—This three-valve engine was supposed to run at 800 r.p.m. at full load. I have run it up to 1000. It is rather noisy at that speed. At low load, it idled as low as 300 r.p.m. The distributing-valve type of engine would run very low indeed; it would idle down to 100 r.p.m. with a heavy flywheel.

QUESTION:—Does fuel dispelled by the fan return to the carbureter?

MR. SARGENT:—Under normal conditions the fuel dispelled by the fan does not return to the carbureter but is converted into gas and returns to the airstream from

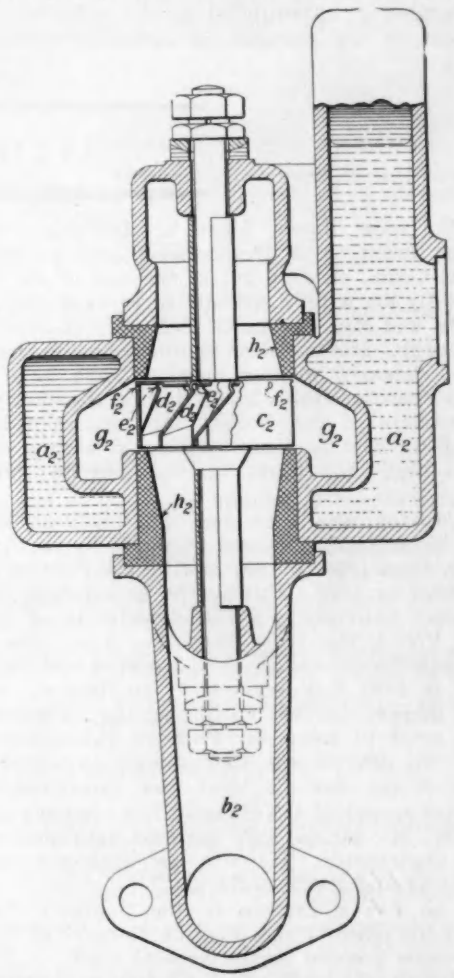

FIG. 4—ENLARGED TRANSVERSE SECTION OF THE GASIFYING DEVICE
The Function of This Device Is To Separate the Particles of Liquid Fuel from the Air Stream and Convert Them into a Dry Gas before They Enter the Cylinders. The Temperature of the Exhaust Passage a_2 Is Maintained Practically Constant through All Ranges of Load, Since Although the Exhaust Passage Becomes Hotter as the Load Increases, More Air Flows Through

which it came. To explain the action of the fan or the liquid separator, I refer to Fig. 4, which is an enlarged transverse section of the device. Liquid fuel floating in or carried along by the airstream consists of little spheres, the surfaces of which only can burn but not until they are converted into gas. Coal, pulverized until it will pass through holes so small that the combined area of 40,000 of them is less than 1 sq. in., is composed of irregular flakes having probably 10 times as much surface per unit of volume as liquid spheres have, travels 50 ft. and requires several seconds of time before it is

consumed. We see then that liquid fuel passing toward the combustion-chamber must be separated from the air and changed into a dry gas before it enters the cylinders, if complete combustion is to be realized. In Fig. 4, a_2 represents the exhaust passage and b_2 the air and fuel leaving the carbureter. As the air carrying the fuel flows toward the combustion-chamber, it drives the fan c_2 at a high velocity. This fan is designed so that the air must change its direction in passing through, about 30 deg., while the liquid spheres, which are about 600 times heavier than the air per unit of volume, going straight ahead, impinge on the inclined blades d_2 and by inertia flow to the gutters e_2 from which by centrifugal force they are thrown through the housing holes f_2 to the chamber g_2 surrounded by the exhaust passage a_2. If the heat in the exhaust is sufficient to convert the liquid into gas, a pressure is generated in g_2 and it works back past the fan edges to the airstream. As the air should not be heated above the dew-point, its temperature is controlled by the thickness of the Bakelite insulators h_2. When the load increases the exhaust passage gets hotter but, as more air flows through, its temperature is maintained practically constant through all ranges of load. As the constant-compression engine described has an abnormally cold exhaust at light load provision was made for returning the heavy fuel to the airstream as it leaves the carbureter. An overflow pipe located ¼ in. below the lower edge of the fan returned the accumulated fuel to the manifold during idling loads but this is unnecessary in standard engines, as the exhaust has sufficient heat even at light loads to vaporize the heavy ends.

ALDEN L. McMURTRY

AFTER a long illness, Alden L. McMurtry, one of the founder members of the Society, died at his home in Greenwich, Conn., on July 26, at the age of 47 years. He is survived by his wife, a son and three daughters. He was a son of Mr. and Mrs. George G. McMurtry of New York City and Pittsburgh. His loss adds another name to the lengthening list of deceased pioneer members who have expended their energies so unselfishly in furthering the welfare, growth and attainments of the Society, and its appreciative expression of its debt to them is mingled with a deep sense of sadness that they could not continue to share in its success.

Mr. McMurtry was born Jan. 15, 1877, at Pittsburgh. Following his schooling, he was employed by the Apollo Iron & Steel Co. from 1894 to 1897 and by the Pressed Steel Car Co. from 1897 to 1899. During the period 1895 to 1897 he built a steam automobile, a full description of which was printed in Vol. I, No. 11 of *Horseless Age*. Also, in 1897 he built a gasoline-driven car that operated successfully; and from 1899 to 1901 was engaged in building an automobile of his own design. In 1901 he formed the Adams-McMurtry Co., which acted as agent for Packard automobiles in New York City. In 1905 he was, as engineer, connected with the New York Motor Car Co. and was associated with the United States agency of the Michelin tire company of France. Subsequently, Mr. McMurtry's business activities related to consulting engineering. He was an authority on motor-vehicle lighting and traffic problems.

In 1918 he was a captain in the Sanitary Corps and stationed in the office of the Surgeon General of the Army. Later he became a major on the General Staff.

Mr. McMurtry was aggressive and fearless. On the night of Feb. 14, 1920, he killed two armed burglars in the cellar of a house at Sound Beach, Conn. Carrying an automatic pistol and accompanied by a companion who was armed only with a small club, he descended into the cellar where he knew the burglars were lurking. In the battle that ensued, in which pistol flashes furnished the only light, he and his companion were the victors, although both were wounded.

In 1921 Mr. McMurtry became consulting engineer for the Motor Vehicle Department of the State of Connecticut and was for a time its chief inspector. In addition to his active and progressive work in regulating the motor-vehicle traffic of the State and in improving the lighting of motor vehicles, he wrote and presented papers on these subjects that form valuable contributions to the literature bearing thereon. His earlier writings, during the period 1907 to 1915, bore such titles as On Timing Automobile Races, An Argument in Favor of the Motorcycle, and Automobile Warning-Signals. These were published. His recent papers were presented before the Metropolitan Section of the Society. Head-Lamp Design and Its Effect Upon Glare Reduction, and Regulating the Use of Motor Vehicles were the titles.

Alden McMurtry, "Mac," as he was widely known, was unique in character. He had a very intriguing sense of humor. He held strong likes and dislikes and did not hesitate to express them openly and forcefully. His sense of right and justice was relentless. Many of the advances made in automobile regulatory matters were due to his efforts. He was a sincere student and advocate of precision and accuracy. He devised many interesting and valuable automotive accessories. The late Professor Hutton aptly called him a mechanical genius.

In the passing of "Mac" we have lost one of the most interesting and best loved figures of the industry. A pioneer, he was consistent, aggressive and helpful to the end. He is sincerely mourned by a great number of friends.

STRENGTH TESTS OF MOTOR-TRUCK WHEELS

(*Concluded from p.* 155)

(5) The cast-steel wheel had high ultimate-strength, but the ratio of proportional limit to weight was 17 per cent less than for the wood wheel. This cast-steel wheel had a low elastic-resiliency value; in the side-thrust test it was one of the best

(6) The steel-disc wheel, like the cast-steel wheel, had a high ultimate-strength, but low specific-strength and low elastic-resiliency. Moreover, this wheel was very weak in side-thrust, due chiefly to the fact that the half-sections did not act as a unit

(7) The rubber-cushion wheel was one of the strongest wheels tested and was the most resilient. Because of the excessive weight of this wheel its specific strength was far below that of the other wheels, but the value of elastic resiliency per pound is far in excess of that of the metal wheels. This wheel is designed for a chain-drive truck; so, the weight of the wheel can be high and the wheel still compare favorably with the other wheels, as the total unsprung weight may not exceed that of another truck using one of the other types of wheel

Applicants *Qualified*

The following applicants have qualified for admission to the Society between June 10 and July 10, 1924. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

ALDUNATE, ALFREDO (J) (mail) 134 West 85th Street, *New York City.*

ARLINGHAUS, FRANK H. (E S) student, Stevens Institute of Technology, Hoboken, N. J., (mail) 209 Jane Street, *Weehawken, N. J.*

ARRONET, LIEUT. HERBERT A. (A) inspector of tanks and tractors, Ordnance Field Service, *Camp Meade, Md.*

BACON, DAVID L. (S M) aeronautical engineer, National Advisory Committee for Aeronautics, Langley Field, *Hampton, Va.*

BARNES, JAMES P. (A) president, Louisville Railway Co., *Louisville, Ky.*

BATCHELDER, FRANK B. (A) supervising engineer, Murray Rubber Co., *Trenton, N. J.*, (mail) P. O. Box 655.

BERGE, LOUIS B. (A) master mechanic, A. C. Spark Plug Co., *Flint, Mich.*, (mail) 205 West Dartmouth Street.

BERNHARDT, LEROY F. (E S) (mail) 796 Glenwood Avenue, *Buffalo.*

BRACE, WILLIAM R. (A) factory manager, J. W. Murray Mfg. Co., *Elizabeth, N. J.*

BRITT, BENJAMIN H. (M) chief engineer, vice-president, Electruck Corporation, *New York City*, (mail) 537 Tinton Avenue.

BROWN, FRANCIS P. (M) Brown & Sharpe Mfg. Co., *Providence, R. I.*, (mail) 594 Public Street.

BRUNSON, CAPT. M. V. (A) Quartermaster Corps, 1819 West Pershing Road, *Chicago.*

COWELL, ROBERT F. (J) assistant chief engineer, Rubber Shock Insulator, Inc., New York City, (mail) 84 Elm Avenue, *Bogota, N. J.*

CRAWFORD, JOSEPH T. (A) manager, automobile sheet department, American Rolling Mill Co., *Middletown, Ohio*, (mail) 408 South Broad Street.

DRUMM, CHARLES F., JR. (M) engineer, assistant chief draftsman, engineering department, International Motor Co., New York City, (mail) 241 14th Avenue, *Long Island City, N. Y.*

DUPONT, PIERRE SAMUEL (M) chairman of board, E. I. duPont de Nemours & Co., 9012 duPont Building, *Wilmington, Del.*; chairman of board, General Motors Corporation, New York City.

GOLDSMITH, JOHN (J) designer, International Motor Co., *New York City*, (mail) 507 West 142nd Street.

GRAVES, W. H. (M) chief metallurgist, Packard Motor Car Co., *Detroit.*

GRUSS, RAYMOND L. (A) president and general manager, Gruss Air Spring Co., *San Francisco*, (mail) 1476 Portola Drive.

HECKLER, L. C. (M) superintendent, Buda Co., *Harvey, Ill.*, (mail) 171 154th Street.

HOSLEY, L. F. (M) manager and chief engineer, DuPont Motors, *Moores, Pa.*

JAY, HAROLD (A) sales engineer, Acklin Stamping Co., *Toledo.*

JOHNSON, HARLEY A. (M) superintendent of shops and equipment, Chicago, North Shore & Milwaukee Railroad Co., Room 1208, 72 West Adams Street, *Chicago.*

KYBURZ, WALTER W. (E S) student, Tri State College, Angola, Ind., (mail) 1000 Madison Street, *Waukesha, Wis.*

LAMKER, HARRY G. (M) foundry superintendent, Wright Aeronautical Corporation, 238 Lewis Street, *Paterson, N. J.*

LAWSON, GUSTAF A. (A) secretary, treasurer and sales manager, Jamestown Car Parts Co., *Jamestown, N. Y.*, (mail) P. O. Box 507.

LEATHERBEE, J. HOWARD (A) Pickering Governor Co., *Portland, Conn.*, (mail) 15 Church Street.

LEROY, CLAUDE ARTHUR (E S) student, Cornell University, Ithaca, N. Y., (mail) 40 East Court Street, *Cortland, N. Y.*

LIPCOT, F. L. (M) chief engineer, Rubber Shock Insulator Co., Inc., *New York City*, (mail) 62 West 93rd Street.

LOUGHEAD, MALCOLM (M) chief engineer, Hydraulic Brake Co., 5833 Russell Street, *Detroit.*

LUCAS, THEODORE (M) chief designing engineer on oil engines, Combustion Utilities Corporation, *New York City*, (mail) 71 West 71st Street.

MCCALMONT, A. W. (M) Vacuum Oil Co., 2631 Woodward Avenue, *Detroit.*

MEAD-MORRISON MFG. CO. (Aff) *East Boston 28, Mass.*
Representative:
Robinson, George E., sales manager.

MIDBOE, G. (M) designer, International Motor Co., New York City, (mail) 1027 71st Street, *Brooklyn, N. Y.*

MILES, BURTIS D. (A) service complaint engineer, International Motor Co., 252 West 64th Street, *New York City.*

MISELL, NEWTON B. (A) director of sales and advertising, Asbestos Textile Co., 18 East 41st Street, *New York City.*

NYE, NORMAN H. (E S) student, University of Akron, Akron, Ohio; layout and detail draftsman, Whitman & Barnes Mfg. Co., *Akron, Ohio*, (mail) 160 South College Street.

OBERLE, DR. A. (M) research technologist, Universal Oil Products Co., Chicago, (mail) 343 South Oak Park Avenue, *Oak Park, Ill.*

OGDEN, CLARENCE E. (A) president and general manager, Automatic Electrical Devices Co., 120 West Third Avenue, *Cincinnati.*

PAYNE, F. G. (F M) P. O. Box 226, *Salisbury, South Rhodesia, Africa.*

PIERCE, WINSLOW S., JR. (A) chief engineer, Ringless Piston Co., Hoboken, N. J., (mail) *Bayville, N. Y.*

PRATT, CECIL F. (A) president and general manager, Sphinx Products Corporation, 510 Van Ness Avenue, *San Francisco.*

REED, CHARLES H. (J) sales manager, Forbes Varnish Co., 3800 West 143rd Street, *Cleveland.*

REHBERGER, EDWARD A. (A) secretary and treasurer, Arthur Rehberger & Son, 320 Ferry Street, *Newark, N. J.*

RESKE, NORMAN W. (J) detailer, Packard Motor Car Co., *Detroit*, (mail) 2634 Chalmers Avenue.

RODGERS, WALTER I., JR. (M) engineer, International Motor Co., New York City, (mail) 304 St. Johns Place, *Brooklyn, N. Y.*

ROTTMUELLER, CARL F. (J) designing draftsman, Ahrens-Fox Fire Engine Co., *Cincinnati*, (mail) 310 Warner Street.

SCHERER, J. OTTO (J) draftsman, engineering department, Ford Motor Co., Dearborn, Mich., (mail) 67 Kirby Avenue, East, *Detroit.*

SCHMIDT, E. P. (J) chief draftsman, Strom Ball Bearing Mfg. Co., (mail) 100 Kimbark Road, *Riverside, Ill.*

SCOTT, RALPH W. (M) draftsman, Reo Motor Car Co., Lansing, Mich., (mail) 1023 Grand River Ave., East, *East Lansing, Mich.*

SCRAGG, GEORGE H. (M) executive, bus department, International Motor Co., *New York City*, (mail) 375 Riverside Drive.

SMITH, CHESTER A. (A) Chevrolet Motor Co., *Atlanta*, (mail) 67 Rosedale Drive.

SMITH, R. D. (M) chief engineer, Mar Tan Motor Mfg. Co., *Milwaukee*, (mail) 1155 National Avenue.

SNOW, EDWARD JAMES (M) manager, commercial car division, Vacuum Oil Co., 61 Broadway, *New York City.*

STILWELL, JOHN (M) general superintendent of transportation, Consolidated Gas Co. of New York, 130 East 15th Street, *New York City.*

STURGES, EDWARD BAKER (M) secretary and treasurer, Weiss Engineering Corporation, 17 Battery Place, *New York City.*

THOMPSON, F. D. (A) lubrication engineer, Vacuum Oil Co., 49 Federal Street, *Boston.*

WATKINS, F. L. (A) salesman and manager of Michigan territory, Jones & Lamson Machine Co., Springfield, Vt., (mail) 1533 Dime Bank Building, *Detroit.*

WEDIN, GEORGE E. (J) engineer, International Harvester Co., 113 East Center Street, *Akron, Ohio.*

WELCH, PHILIP J. (A) assistant tool engineer, Motor Wheel Corporation, Lansing, Mich., (mail) 2614 St. Clair Avenue, *Detroit.*

WHITE, GERALD TAYLOR (M) editor, Rudder Publishing Co., 9 Murray Street, *New York City.*

Applicants *for* Membership

The applications for membership received between June 14 and July 15, 1924, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ABEYDEERA, A., Y. M. C. A., *Bangalore City, India.*

BAER, BANKARD F., instructor in Motor Transport School, *Camp Holabird, Md.*

BOLKOVITINOFF, N. F., tractor engineer of the People's Commissariat of Agriculture, *Moscow, Russia.*

BOUKARD, SAMUEL L., salesman, Pacific Nash Motor Co., *San Francisco.*

BUCHANAN, HUGH, experimental and research work, Hupp Motor Car Corporation, *Detroit.*

BURGEY, FIRST LIEUT. SAMUEL S., Ordnance Department, Watertown Arsenal, *Watertown, Mass.*

BYCE, LISLE D., general superintendent, Ottawa Car Mfg. Co., Ltd., *Ottawa, Ont., Canada.*

CHARLES, MILTON C., student, Polytechnic Institute of Brooklyn, *Brooklyn, N. Y.*

CLARK, EUGENE C., engineer, International Motor Co., *New York City.*

CONNOR, KIRKE W., secretary, Ditzler Color Co., *Detroit.*

COOK, ROBERT G., engineer, Ingersoll-Rand Co., *Phillipsburg, N. J.*

CREAMER, CHARLES C., instructor, Michigan State Automobile School, *Detroit.*

CRONK, HARVEY MORTON, aeronautical engineer and mechanical engineer, *New York City.*

DONALD, ALEXANDER, manufacturer, Canada Wire & Iron Goods Co., *Hamilton, Ont. Canada.*

DUNGAN, FRANK F., service department, White Co., *Indianapolis.*

EDMONDSON, O. L., New York manager, Westinghouse Air Spring Co., *Long Island City, N. Y.*

EMERSON, GEORGE B., general manager and engineer, Motor Parts Service Co., *Detroit.*

GERM, F. E., owner of machine shop and garage, *Streator, Ill.*

GROSS, CHARLES, designing engineer, Fairbanks, Morse & Co., *Three Rivers, Mich.*

GUAY, E. J., electrical engineer and mechanical engineer, General Electric Co., *Lynn, Mass.*

HANSEN, F. N., special representative, Vacuum Oil Co., *Milwaukee.*

HORNING, SAMUEL D., manager, Monarch Auto School, *Tulsa, Okla.*

HULLEY, W. H., chief of road testing, Rolls-Royce of America, *Springfield, Mass.*

HUXLEY, T. C., JR., branch manager, Diamond T Motor Car Co., *Chicago.*

JOHNSON, CHARLES L., automobile mechanic, operating tractor car for Albert Keene, *Sturgis, S. D.*

JOHNSON, THOMAS B., superintendent of garages, Marshall Field & Co., *Chicago.*

JONES, JAMES R., general manager, Bossert Corporation, *Utica, N. Y.*

KERR, STEPHEN L., mechanical superintendent, Covey-Ballard Motor Co., *Salt Lake City, Utah.*

KISTER, NORMAN M., draftsman, U. S. Axle Co., *Pottstown, Pa.*

LENCKE, JOHN K., president and general manager, Apollo Magneto Corporation, *Kingston, N. Y.*

LEPAGE, W. LAURENCE, research engineer, department of aeronautics, Massachusetts Institute of Technology, *Cambridge, Mass.*

LEWIS, H. C., president, Coyne Electrical School, *Chicago.*

MCCANNA, JOHN F., patent lawyer, Wilson & McCanna, *Rockford, Ill.*

MAEDLER, FRANZ L., consulting engineer, Maedler Syndicate, *Cleveland.*

MANSUX, C. W., assistant engineer, General Electric Co., *Lynn, Mass.*

MARSHALL, LEWIS K., mechanical engineer, General Motors Research Corporation, *Dayton, Ohio.*

MINCHIN, HENRY C., president and general manager, New England Motor Sales Co., *Greenwich, Conn.*

MOORE, WARREN A., student, Tri-State College, *Angola, Ind.*

MORRELL, JOSEPH C., inspector, automotive division, Westinghouse Air Brake Co., *Wilmerding, Pa.*

PULLEYBLANK, H. E., sales engineer, Universal Products Co., *Detroit.*

RAYNOLDS, JOHN F., president, Paraflector Co., *Minneapolis.*

RINEHART, C. R., vice-president, Overman Cushion Tire Co., *New York City.*

ROSS, E. R., assistant chief engineer, Raybestos Co., *Bridgeport, Conn.*

ROSSI, LOUIS M., vice-president, Bakelite Corporation, *Perth Amboy, N. J.*

SMITH, VERNON A., vice-president and general manager, Kenworth Motor Truck Corporation, *Seattle.*

SPROULL, J. C., engineer of tests, B. F. Goodrich Co., *Akron, Ohio.*

THEE, FIRST-LIEUT. WALTER C., Quartermaster Corps, *City of Washington.*

TIERNEY, J. W., sales engineer, Electric Storage Battery Co., *Chicago.*

WARNER, JAY LAVERNE, special representative, Mack International Motor Truck Corporation, *Seattle.*

WATT, W. WALTER, automobile dealer, Hillcrest Garage, *Halifax, N. S., Canada.*

WHITE, JULIAN M., general manager, Automotive Electric Service Co., *Sioux City, Iowa.*

WILLMAN, GEORGE L., advertising agency, Lord & Thomas, *Chicago.*

WILSON, PAUL DUDLEY, sales manager, Bassick Mfg. Co., *Chicago.*

WINTER, HERBERT G., student, University of Michigan, *Ann Arbor, Mich.*

YOUNG, RAYMOND W., automotive engineer, P. P. Young Construction Co., *St. Joseph, Mo.*